MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. L. FEBRUARY 14, 1890. No. 4

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

James Blair Forgan, 15 Pall Mall, S.W.;
Richard A. Gregory, Science Schools, South Kensington, and 115 Rylston Road, Fulham, S.W.;
Alfred Newton Harris, 21 Lambhay Street, Plymouth;
Frederick William Henkel, jun., 32 Berwick Road, Walthamstow,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election, the names of the proposers from personal knowledge being appended:—

Sir George Errington, Lackham Manor, and Brooks's Club (proposed by the Earl of Crawford, and Baron de Worms);
Edward Robinson, 4 Castelnau Gardens, Barnes, S.W. (proposed by A. Cowper Ranyard);
Andrew Simons, H.M. Dockyard Schools, Devonport (proposed by T. Archer Hirst).

REPORT OF THE COUNCIL TO THE SEVENTIETH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1888	230	360	3	593	47	1	641
Since elected	+8	+16	...	...	+4	...	...
Deceased	−7	−6	...	...	−3	...	...
Resigned	...	−7	...	...	...	...	...
Expelled	...	−2	...	...	...	...	...
Removals	+3	−3	...	...	...	...	...
December 31, 1889	234	358	3	595	48	1	644

Mr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, January 1, 1889:—						
at Bankers', as per pass book	345	19	8			
„ on Deposit Account	300	0	0			
in hand of Assistant Secretary on account of Turnor and Horrox Fund	0	14	10			
in hand of Assistant Secretary on Petty Cash Account	4	15	5			
				651	9	11
Dividends on £13,200 Consols	370	0	6			
„ £750 Metropolitan Stock	21	19	0			
				391	19	6
Received on account of Subscriptions:—						
Arrears	129	3	0			
238 Annual Contributions for 1889	499	16	0			
3 „ „ 1890	6	6	0			
23 Admission Fees	48	6	0			
17 First Contributions	26	5	0			
				709	16	0
10 Composition Fees				210	0	0
Sales of Publications:—						
At Williams and Norgate's, 1888	36	7	1			
At Society's Rooms, 1889	39	0	3			
				75	7	4

Audited and found correct 1890 Jan. 8.

W. B. Gibbs,
Robt. J. Lecky,
Edwd. W. Maunder.

£2,038 12 9

Astronomical Society, from January 1 to December 31, 1889.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
,, ,, for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
Income Tax and House Duty	10	10	0			
Fire Insurance	7	16	6			
				18	6	6
Printing, &c.	325	18	0			
Lithography and Engraving	24	0	6			
				349	18	6
Computation of Ephemerides	50	0	0			
Lunar Computations	10	18	6			
				60	18	6
Turnor and Horrox Fund: purchases for Library	15	1	5			
Binding Books in Library	22	19	11			
				38	1	4
House Expenses	31	6	4			
Wages	32	14	0			
Postage, &c.	60	4	10			
Carriage of Parcels	2	8	10			
Stationery and Office Expenses	8	7	11			
Expenses of Meetings	22	2	0			
Fittings and Repairs	7	17	3			
Coals and Gas	59	3	9			
Electric Lighting Expenses	8	13	10			
Time Signal: Rental of Wire	5	0	0			
Assistance rearranging Books, &c.	4	15	6			
Advertising	1	19	6			
Sundries	7	16	5			
				252	10	2
Mrs. Jackson Gwilt's Annuity				8	19	0
Lee and Janson Fund Grants				10	0	0
Bankers' Deductions on Cheques, &c.				0	2	3
Balances, December 31, 1889:—						
at Bankers', as per pass book	488	18	7			
,, on Deposit Account	500	0	0			
in hand of Assistant Secretary on account of Turnor and Horrox Fund	4	13	5			
in hand of Assistant Secretary on Petty Cash Account	6	4	6			
				999	16	6
				£2,038	12	9

Assets and Present Property of the Society, January 1, 1890.

	£	s.	d.	£	s.	d.
Balances, December 31, 1889:—						
At Bankers', as per Pass Book	488	18	7			
„ on Deposit Account	500	0	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	4	13	5			
In hand of Assistant Secretary on Petty Cash Account	6	4	6			
				999	16	6
Due on account of Subscriptions:—						
1 Contribution of 4 years' standing	8	8	0			
12 Contributions of 3 „	75	12	0			
34 „ 2 „	142	16	0			
83 „ 1 year's standing ...	174	6	0			
2 Admission Fees and 1st Subscriptions	6	6	0			
	407	8	0			
Less 3 Contributions paid in advance ...	6	6	0			
				401	2	0
Due from Messrs. Williams and Norgate for sales of Publications during 1889				22	19	0
£7,500 $2\frac{3}{4}$ per Cent. Consols, including the Lee and Janson Fund, and the Turnor and Horrox Memorial Funds.						
£5,700 $2\frac{3}{4}$ per Cent. Consols, including Mrs. Jackson Gwilt's gift (£300).						
£750 Metropolitan 3 per Cent. Stock.						
Astronomical and other Manuscripts, Books, Prints, Instruments, and Furniture.						
Unsold Publications of the Society.						

Report of the Auditors.

We have examined the Treasurer's accounts, and have found and certified the same to be correct. The cash in hand on Dec. 31, 1889, including the balance at the bankers', and a sum of 500*l.* on deposit, amounted to 999*l.* 16*s.* 6*d.*

The funded property of the Society is the same as at the end of last year.

The books, instruments, and other effects have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

(Signed) W. B. Gibbs,
Robt. J. Lecky,
Edwd. W. Maunder.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXIX.	406	...
I. Part 2	35	...	XXX.	159	1
II. Part 1	55	...	XXXI.	142	...
II. Part 2	20	...	XXXII.	154	1
III. Part 1	63	1	XXXIII.	163	...
III. Part 2	85	1	XXXIV.	164	4
IV. Part 1	78	3	XXXV.	108	5
IV. Part 2	91	3	XXXVI.	196	8
V.	105	3	XXXVII. Part 1	336	8
VI.	124	3	XXXVII. Part 2	285	8
VII.	148	3	XXXVIII.	271	...
VIII.	127	3	XXXIX. Part 1	242	4
IX.	134	3	XXXIX. Part 2	246	3
X.	140	...	XL.	243	...
XI.	153	...	XLI.	412	...
XII.	159	...	XLII.	233	3
XIII.	163	...	XLIII.	235	1
XIV.	367	2	XLIV.	217	...
XV.	140	...	XLV.	248	1
XVI.	165	...	XLVI.	234	2
XVII.	147	1	XLVII. Part 1	3	...
XVIII.	141	...	XLVII. Part 2	18	...
XIX.	148	...	XLVII. Part 3	2	...
XX.	142	...	XLVII. Part 4	10	...
XXI. Part 1	308	...	XLVII. Part 5	10	...
XXI. Part 2	98	...	XLVII. Part 6	10	...
XXI. 1 & 2 (together)	61	...	XLVII.	216	2
XXII.	164	...	XLVIII. Part 1	261	3
XXIII.	150	...	XLVIII. Part 2	272	1
XXIV.	156	...	XLIX. Part 1	537	...
XXV.	166	...	Index to *Memoirs*	644	1
XXVI.	172	...			
XXVII.	424	...			
XXVIII.	382	...			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	65	...	XXVI.	11	...
II.	67	...	XXVII.	4	...
III.	...	...	XXVIII.	73	...
IV.	...	...	XXIX.	53	...
V.	...	...	XXX.	66	2
VI.	52	...	XXXI.	94	...
VII.	2	...	XXXII.	117	5
VIII.	154	2	XXXIII.	98	2
IX.	24	3	XXXIV.	77	2
X.	180	1	XXXV.	58	1
XI.	185	1	XXXVI.	32	1
XII.	109	2	XXXVII.	44	3
XIII.	178	3	XXXVIII.	97	2
XIV.	178	3	XXXIX.	102	1
XV.	170	2	XL.	113	3
XVI.	155	2	XLI.	113	5
XVII.	167	1	XLII.	122	1
XVIII.	246	...	XLIII.	122	1
XIX.	58	...	XLIV.	125	...
XX.	34	...	XLV.	125	3
XXI.	17	...	XLVI.	119	3
XXII.	33	...	XLVII.	127	5
XXIII.	19	...	XLVIII.	129	6
XXIV.	24	...	XLIX.	149	...
XXV.	15	...	Index ...	565	1

Library Catalogue 606

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to XLIX. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.

No. 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth ; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3) Equatoreal stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost) ; double-image micrometer; two wire micrometers ; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand ; double-image micrometer ; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand ; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2 foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers ; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided

on platinum, with counterpoise stand and artificial horizon.

No. 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40 (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

No. 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. 3¼-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum with 5-foot brass suspension rod, working on knife edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.
„ 91. Astronomical time watchcase, by Professor Chevallier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2 feet 6 inch navy telescope with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer & Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatoreal sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 116. A pair of 18-inch globes.
„ 117, „ 118. Two old sun-dials.

No. 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. $3\frac{1}{2}$-in. portable refracting telescope, by Tulley, with tripod stand (bequeathed by the late Mr. W. H. Bartlett).

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 5. Herschel 7-foot reflector (two mirrors only), to Mr. A. A. Common.
„ 9. 7-foot Gregorian reflector (mirror only), to Mr. A. A. Common.
„ 10. Variation transit, to Mr. Maxwell Hall.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 22. The *Matthew* equatoreal, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. (1) 30-in. transit and one stand, to Mr. C. Thwaites.
„ 28. (2) 6-inch theodolite and stand, to Mr. A. A. Common.
„ 29. (3) Equatoreal mounting, clock movement, and pillar, to Mr. W. Peck.
„ „ Wire micrometer (No. 1), to Mr. C. Thwaites.
„ „ Wire micrometer (No. 2), to Mr. Maxwell Hall.
„ 30. (4) $3\frac{1}{4}$-inch equatoreal and stand, to Mr. E. B. Powell.
„ „ „ Double image micrometer, to Mr. Maxwell Hall.
„ 34. (8) Transit instrument and stand, to Professor C. Pritchard.
„ 38. (12) 18-inch *Borda* repeating circle, to Mr. Maxwell Hall.
„ 39. (13) 8-inch repeating circle, to Mr. J. Norman Lockyer.
„ 42. (16) 10-inch reflecting circle and stand, to the Rev. H. P. Slade.
„ „ „ Artificial horizon, roof, and mercury bottle, to Mr. C. Thwaites.
„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.
„ 52. (26) Dipping needle, to Mr. Maxwell Hall.

No. 54. (28) Magnetic intensity needle, to Mr. Maxwell Hall.
,, 69. (43) Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
,, 78. 9¼-inch reflector and stand, to Mr. Maxwell Hall.
,, 79. Spectroscope, to Mr. Maxwell Hall.
,, 86. 4½-inch Gregorian reflector by Short (two mirrors only), to Mr. A. A. Common.
,, 122. 6-inch speculum and flat, to Mr. A. A. Common.
,, 123. 6-in. refractor by Grubb, to the Rev. A. Freeman.
,, 124. Position micrometer by Cooke, to Mr. J. E. Drower.
,, 126. 3½-inch portable refracting telescope by Tulley, to Dr. S. Johnson.

The Gold Medal.

No Gold Medal has been awarded by the Council this year.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year:—

Fellows:—Major-General John Baillie.
Thomas Bauchope.
Warren De la Rue.
H. S. W. Evans.
Charles Hood.
R. S. Newall.
Rev. S. Parkinson.
Rev. S. J. Perry.
G. E. Ranken.
G. F. Riddiford.
G. W. Royston-Pigott.
James Smith.
C. J. Lambert (1888).

Associates:—Gaetano Cacciatore.
Lorenzo Respighi.
Wilhelm Tempel.

Thomas Bauchope was born at Brucefield, in Midlothian, in the year 1823, and succeeded his father as factor on several estates in Midlothian. In this position he earned for many years the confidence and the esteem of all with whom he had dealings. He combined with other professional duties those of a land surveyor; but the chief delight of his life was the science of astronomy, which he pursued with all the ardour of a devoted student.

For many years he made observations with a telescope he had mounted in his garden, and only a short time before his death he had ordered a much more powerful instrument, for which he had erected a new observatory. He contributed a series of popular articles on astronomy to a local newspaper. He was of a modest and retiring disposition, of a kindly heart, and gentle and unobtrusive in his manner. Nothing gave him greater pleasure than to find some working-man or young person exhibiting an interest in the science which brought such delight to himself.

Mr. Bauchope was elected a Fellow of this Society November 11, 1887.

Warren De la Rue was born at Guernsey on January 18, 1815, and was the son of Mr. Thomas De la Rue, the founder of the eminent firm of manufacturing stationers in London. He was educated at the College Saint-Barbe in Paris, where he remained until he returned to London to enter his father's business.

But little, unfortunately, is known of the early career of one who in after life occupied so distinguished a position in the scientific world.

From an early age mechanics and machinery had a strong attraction for him, and possessing a shrewd inventive faculty, he devoted himself so successfully to technical work that he became a good engineer without having received any special training. His mechanical skill was evidently of a high order, and found its appreciation among those with whom he was associated, for at the early age of 23 he was entrusted with the erection of some large white lead works, the drawings for which he made entirely himself. Mr. De la Rue's ability and intelligence at this time are well displayed in the fact that his drawings were found to be so carefully prepared as to need no alteration, and the works were erected upon his designs with entire satisfaction.

Some year or two before this period he had begun to devote himself in his leisure to electrical researches, in which he afterwards attained so eminent a position. The first scientific paper he appears to have published was one dated September 15, 1836, when he was living in Bunhill Row, and which is printed in the *Philosophical Magazine* for December of that year, "On Voltaic Electricity, and on the Effects of a Battery charged with Sulphate of Copper." In this paper he gives an account of experiments made with a battery in which he used a saturated solution of sulphate of copper as the exciting agent. This principle had independently been employed by Daniel in his researches in voltaic electricity, but was relinquished by him as it failed to give a constant combination.

From this time until 1848 Mr. De la Rue appears to have devoted his scientific thoughts mainly to chemical and physical researches, for in this period we find papers by him "On the Agency of Caloric," "On the Structure of Electro-precipitated Metals," "On a Crystallised Alloy of Zinc, Iron, Lead and Copper," and "On Cochineal."

The earliest mention in the *Monthly Notices* of his attention being directed to astronomy appears in the number for December 1850, when a very beautiful drawing of *Saturn*, made by him with his 13-inch reflector, is announced to be exhibited the following month. This drawing fully confirmed Mr. Bond's discovery of the crape ring made on the 15th of the previous month. The same number of the *Monthly Notices* contains a brief note by Mr. De la Rue on his method of drawing double stars and nebulæ, which indicates that for some time previous to

this period he was in the habit of making observations of these objects with his large reflector.

This is the first reference to a telescope which afterwards became celebrated, and its history has, therefore, considerable interest. It was an equatorially mounted reflector of 13 inches aperture and 10 feet focal length, made in his own workshop, the optical portion being entirely his own handiwork.

From the following interesting reminiscence of him by Mr. James Nasmyth, we learn not only the origin of this historic telescope, but we ascertain also that Mr. De la Rue's thoughts were inclined to astronomy as early as the year 1840:

"I well remember the visit I received from my dear friend Warren De la Rue in the year 1840. I was executing some work for him with respect to a new process which he had contrived for the production of white lead. I was then busy with the casting of my 13-inch speculum. He watched my proceedings with earnest interest and most careful attention. He told me many years after that it was the sight of my special process of casting a sound speculum that in a manner caused him to turn his thoughts to practical astronomy, a subject in which he has exhibited such noble devotion as well as masterly skill. Soon after his visit I had the honour of casting for him a 13-inch speculum, which he afterwards ground and polished by a method of his own."

He was well acquainted with the labours of both Mr. Lassell and Mr. Nasmyth in the construction of telescopes, as is shown by the ready acknowledgment he made to the former "for his communication from time to time of his methods of manipulation," and to the latter "for many most valuable hints in polishing and grinding, more particularly for imparting to him a plan of producing a beautiful uniform surface to specula previous to the final pitch polishing." Indeed, it was Mr. Nasmyth who planted the germ that developed into the love for astronomy which characterised Mr. De la Rue throughout his life. The admission of this fact is contained in a letter to him from Cranford in 1864, in which he says, "No one has so great a claim on the fruit of my labours; for you inoculated me with the love of star-gazing, and gave me invaluable aid and advice in figuring specula." This impulse wrought upon Mr. De la Rue's rare mechanical genius, so that he was able to effect improvements in the most approved methods of polishing the specula of reflecting telescopes, and perfecting the mechanical arrangements by which operations of such refined nicety are performed.

The mechanical means he adopted for figuring specula are fully described in his paper in the *Monthly Notices* for December 1852, upon which Sir John Herschel has thus commented: "Mr. De la Rue's machinery, though grounded on Mr. Lassell's rotatory principle, is by no means a servile imitation of Mr. Lassell, inasmuch as several distinct improvements have been introduced

tending to distribute the polishing action more equally over the whole surface of the metal. One of these improvements consists in his interposition of a plate between the supporting plate and sliding plate of Mr. Lassell's traversing slide, which being made to revolve, causes the traversing movement of the speculum to take place, not across the same diameter of its area, but at every stroke across a different diameter; and he also obviates the irregularity of the motion of Mr. Lassell's polisher on its centre, by governing that rotation by mechanism instead of leaving it to be determined by the excess of external over internal friction." . . . "Such is Mr. De la Rue's mechanism, which has afforded very admirable results in the production of specula of 13 inches in diameter and 10 feet focal length, the perfection of which is enhanced by his practice of bestowing the same care and precision on every step of the figuring of the speculum, from the grinding, the smoothing on a bed of hones, or rather a slab of slate cut into squares,* carefully brought to the same figure, and to the figuring of the polisher itself, which being thus previously rendered almost perfect, the speculum is saved the rough work of having to figure the polisher for itself on every occasion of repolishing."

It was the possession of this telescope of surpassing excellence, that subsequently enabled Mr. De la Rue to produce results in celestial photography and planetary delineation of such high and enduring value.

In 1851 and 1852 he demonstrated "his rare skill as a draughtsman as well as an observer" by the drawings of *Mars* and *Saturn* which he presented to this Society. He continued such observations for some years until he had achieved those unexampled representations of the planets, with which all are familiar, and which stand as models for imitation.

In 1851 Mr. De la Rue's attention was vividly attracted to a Daguerreotype of the Moon which was exhibited at the Great Exhibition of that year. This had been taken by William Cranch Bond in the focus of the great 15-inch refractor of the Observatory of Harvard College. Some Daguerreotypes of the Moon, taken by Messrs Whipple and Jones of Boston with the same instrument, were also exhibited at the meeting of this Society on May 9, 1851.

It was the sight of these very promising photographs which first gave the impulse to Mr. De la Rue's labours in this direction, and to the new field of research thus revealed, he at once devoted himself with an intelligent skill that soon made him the foremost pioneer of celestial photography in this country.

From the epoch of the first researches in photography by

* Mr. De la Rue's alteration of the plan adopted by Mr. Nasmyth consisted in substituting a slab of common slate for a grinder made up of squares of German blue stone (hone); the former having the advantage of always retaining its figure, which the hone-tool does not, when laid on one side for any length of time.

Daguerre in 1839 to the present day, the great progress of photographic science is mainly due to the successive introduction of two important methods—the first, the discovery in 1851 by Mr. Scott Archer, Mr. Fry, and Dr. Diamond of the advantages offered by collodion as the medium for the sensitive film, and the second, the invention of the dry gelatine plate. The collodion process was brought into practical operation at a time coincident with the exhibition in London of the Harvard pictures of the Moon. Mr. De la Rue was not slow to avail himself of a method which offered such enormous advantages over that discovered by Daguerre.

At the latter end of 1852 he made some successful positive photographs of the Moon, employing the reflecting telescope already referred to, which was then mounted in the garden of his residence at Canonbury. The necessary exposure was from ten to thirty seconds, the images having a diameter of $1\frac{1}{10}$ inch. The plan of operations may be best described in his own words. "In taking these early photographs, I was assisted by my friend Mr. Thornthwaite who was familiar with the employment of the new medium (collodion). At that period, I had not applied any mechanical driving motion to the telescope, so that I was constrained to contrive some other means of following the Moon's apparent motion; this was accomplished by hand; in the first instance by keeping a lunar crater always on the wire of the finder by means of the ordinary handgear of the telescope, but afterwards by means of a sliding frame fixed in the eyepiece holder, the motion of the slide being adjustable to suit the apparent motion of our satellite; the pictorial image of the Moon could be seen through the collodion film, and could be rendered immovable in relation to the collodion plate, by causing one of the craters to remain always in apparent contact with a broad wire placed in the focus of a compound microscope, affixed at the back of the little camera-box which held the plate." Notwithstanding the absence of any automatic driving motion, several good positive pictures of the Moon were obtained, but the difficulties encountered were so great that experiments were discontinued until such time as clock motion could be applied to the instrument. This was not accomplished until the year 1857, when Mr. De la Rue removed from Canonbury to Cranford in Middlesex. There he mounted the telescope with a remarkably good driving-clock, and resumed his experiments in celestial photography. At the November meeting of this Society in that year he exhibited some beautiful photographs of the Moon obtained under these new conditions.

In his first attempts, he obtained positive pictures, but in 1857, he made experiments with negative collodion plates, not only because they admitted of more easy multiplication, but mainly because the image was finer in grain. Employing a method suggested to him by Mr. Howlett, he was able to obtain good negatives with an exposure of 10 seconds.

Mr. De la Rue's pictures of the Moon possessed great sharpness of definition and accuracy of detail, and admitted of considerable amplification—they would indeed bear examination under a magnifying power of 16. Until the appearance in 1865 of Mr. Rutherfurd's pictures of the Moon, the Cranford lunar photographs remained unequalled, to testify to the assiduity and skill he had displayed in overcoming all the difficulties attendant upon their production.

Mr. Wheatstone's ingenious invention of the stereoscope suggested to Mr. De la Rue the happy idea of combining, by means of that instrument, photographs of the Moon of the same phase, but differing only in libration. Upon these stereoscopic pictures Sir John Herschel has remarked: "Nothing can surpass the impression of real corporeal form thus conveyed by some of these pictures, as taken by Mr. De la Rue with his powerful reflector, the production of which (as a step in some sort taken by man outside of the planet he inhabits) is one of the most remarkable and unexpected triumphs of scientific art."

On comparing the photographs with the image of the Moon viewed in the telescope, Mr. De la Rue discovered two important features, which he announced to this Society in November 1857. He found that points on the lunar surface which have optically equal intensity of light, do not produce equally brilliant positive, and equally obscure negative impressions; and he also observed that those portions of the lunar surface which are illuminated by a very oblique ray from the Sun, do not produce an equal effect on the sensitive plate, though they are equally bright to the eye.

At the meeting in the following month, he exhibited some photographs of great beauty of *Jupiter*, *Saturn*, and the double star *Castor*. On that occasion he read a noteworthy paper on the photographic determination of the relative light of the Moon and the planets *Jupiter* and *Saturn*—the important conclusions to which he came were that the actinic power of the Moon to *Jupiter* is about six to five or six to four; and that the chemical rays of *Jupiter* are twelve times more energetic than those of *Saturn*.

Mr. De la Rue's connection with solar physics may be said to date from the early part of the year 1854. In April of that year Sir John Herschel suggested to the Kew Committee of the British Association that arrangements should be made for securing daily photographic representations of the Sun. He considered that a telescope with a 3-inch object-glass would be sufficiently powerful, and advised that the image should be formed not in the focus of the object-glass, but in that of a secondary magnifier. The object of this arrangement was to obtain a considerably magnified image of the Sun, and also to allow of a system of spider lines being photographed on the plate. On May 3 the Kew Committee requested Mr. De la Rue to ascertain the probable cost of such an apparatus. On the 29th of the following June the Council of the Royal Society, in

consequence of an application made to them on the subject, decided to grant the necessary funds, and the instrument was forthwith constructed by the late Mr. Ross. It should be noted, however, that the cost of this photographic apparatus was eventually defrayed out of a fund placed at the disposal of the Council of the Royal Society by the late Mr. Oliveira.

The photoheliograph, which is an equatorially-mounted photographic telescope, was devised entirely by Mr. De la Rue. It had an object-glass of $3\frac{4}{10}$ inches aperture * and 50 inches focal length. It was not corrected for achromatism in the ordinary manner, but so as to produce a coincidence of the visual and photogenic foci. The secondary magnifier was of the Huyghenian form, with a system of fixed micrometer wires between the lenses.

The Kew solar photographic operations were inaugurated by Mr. De la Rue in March 1858, when the first pictures were obtained. The subsequent observations are too well known to need detailed description. The work was continued regularly for fourteen years—1858–1872—when it was discontinued at Kew, and the instrument transferred to Greenwich, where photoheliographic observations have since formed part of the routine work of the Royal Observatory. The results were communicated to the Royal Society in a series of important memoirs by Mr. De la Rue in conjunction with Professor Balfour Stewart and Mr. Loewy, entitled "Researches on Solar Physics." The credit of having successfully established a convenient system for the daily record by photography of the condition of the Sun's visible surface belongs undoubtedly to Mr. De la Rue.

At the meeting of the British Association at Aberdeen in 1859, Mr. De la Rue presented an exhaustive report "On the State of Celestial Photography in England" at that time. This paper forms a most complete and valuable monograph on the art, in which all instrumental, chemical and astronomical questions bearing on the subject are succinctly described and explained. Attention had been directed to celestial photography in this country for eight years, but though some other observers had occasionally made experiments, there had been no systematic pursuit of this branch of astronomy in England except by Mr. De la Rue in his own observatory, or under his immediate superintendence at Kew.

At this time Mr. De la Rue had decided to take the Kew photoheliograph out to Spain, to endeavour to photograph the red flames which might be seen during the total solar eclipse of July 18, 1860; but he had doubts whether the light

* The aperture of the telescope was usually reduced to two inches, as early experiments led him to conclude that, for an image of the Sun of any given size, when once the aperture of the telescope which is sufficient to produce the picture with the necessary degree of rapidity has been ascertained, it is not beneficial to increase that aperture; that is to say, no more details are depicted, nor does the picture become sharper than when the smaller aperture is used.

of the prominences would be sufficiently intense to imprint themselves on the sensitive plate. He had formed the opinion that the light of the corona and red flames taken together was not greater than the light of the full Moon, and he found that with an exposure of three minutes, employing the full aperture of the photoheliograph, he could obtain only a very faint impression of the Moon. The well-known expedition to Spain, which he has described so fully and so graphically in the Bakerian Lecture for 1862, was therefore undertaken with considerable misgiving as to the results that might be secured. Those results are now matter of history. The two photographs, which were obtained during totality, each with an exposure of sixty seconds, when compared with the photographs taken by Padre Secchi at a position some 250 miles distant, removed all remaining doubts as to the real existence and solar character of the red flames, by exhibiting them on the plates gradually covered up on one side, and uncovered on the other side of the Sun, by the progress of the Moon. Mr. De la Rue's comparison of these photographs showed that the images of the prominences in both series accorded in their most minute details; and he establishes an important point in the following words: "The photographs must, from the difference of position of the two stations, have been made at an absolute interval of about seven minutes; and this fact, while it strongly supports the conclusion that the protuberances belong to the Sun, at the same time shows that there is no change in their form during an interval much greater than the whole duration of an eclipse."

In the history of celestial photography in this country Mr. De la Rue stands pre-eminent. Perhaps no words could define his position with greater justice, than those made use of by the late Dr. Lee in presenting to him the Gold Medal of this Society: "Mr. De la Rue's claim to the special notice of astronomers, as a delineator of celestial objects through the medium of photography, does not rest on the absolute priority of his application of a well-known art in a new direction. It is rather based on the fact that, by methods and adaptations peculiarly his own, he has been the first to obtain automatic pictures of the Sun and Moon, sufficiently delicate in their detail to advance our knowledge regarding the physical characters of those bodies, and admitting of measurements astronomically precise." The tribute that was then paid to a mind so highly cultivated, whose energy had been directed for so many years to the attainment of scientific perfection, met with a wide sympathetic response.

In 1864 he was elected President of this Society; and the period for which he held that position was marked by the delivery of two very able addresses: the first in presenting the Gold Medal, in 1865, to Professor G. P. Bond for his work on Donati's Comet; and the second in 1866, when a like honour was awarded to Professor Adams for his contributions to the Lunar Theory.

In 1873 Mr. De la Rue terminated his observational labours in astronomy by offering to the University of Oxford his far-famed reflecting telescope and the greater part of the contents of his observatory, on the sole condition that they should be usefully employed. On November 27 of the same year Convocation accepted this generous gift, and authorised the expenditure of a sum of money for the erection of suitable buildings. His sympathy with practical astronomy was now transferred to Oxford, and henceforth it was a constant pleasure to him to assist and encourage the excellent work of the observatory that sheltered his old telescope.

In 1887 he took great interest in Admiral Mouchez's scheme for charting the heavens by means of photography, which was discussed at the International Congress, that assembled at Paris in April of that year; and on becoming acquainted with the results of the conference, he, in the most generous and liberal spirit, placed a considerable sum of money at the disposal of the Oxford University Observatory, to provide a suitable photographic telescope, so as to enable its distinguished director to take a full share in this important undertaking.

In 1873 Mr. De la Rue had removed from Cranford to London, and in the following year he fitted up a private physical laboratory near his house in Portland Place, where, employing a battery at first of 11,000, and finally of 15,000 chloride of silver cells, he, in conjunction with Dr. Hugo Müller, carried on an elaborate series of researches on the electrical discharge. The results were communicated to the Royal Society in a series of four Memoirs published in the *Philosophical Transactions*.

It remains but to mention that over a long period he pursued many important chemical researches which met the appreciation and recognition of the Chemical Society by his election to the president's chair for two periods, viz. from 1867 to 1869, and again from 1879 to 1880. We have already referred to some of his early papers. The nature of his chemical work appears to have been mainly technological, and the discoveries he made were, in one case at least, of considerable pecuniary value to him. At the Great Exhibition of 1851, Mr. De la Rue was a member of the jury, and reporter of Class XXIX. In this connection his attention was particularly attracted to the processes and manufacture of Price's Patent Candle Company, and the interest he took in the matter is shown by the Jury Report. He subsequently made some researches on "Rangoon Tar," published in the Proceedings of the Royal Society, which led him to patent a process to improve the special manufacture of Messrs. Price & Co., from whom, in consequence, he received a considerable sum of money. In his own business, his scientific knowledge enabled him to introduce a great number of improvements in processes and machinery which cannot be more particularly referred to here, but conspicuous among them may be mentioned the envelope-making

machine, which was one of the attractions of the Exhibition of 1851.

It is impossible in this brief notice to adequately record all the eminent services to science rendered by Mr. De la Rue. The various papers and memoirs that will be found in the Transactions of the Royal, the Royal Astronomical, the Chemical and other societies, testify to his genius and consummate skill in those branches of practical astronomy, solar physics, and technical chemistry with which he was peculiarly identified. But there is no record of what constitutes one important item in the sum of his usefulness; for it is only those who served and were associated with him on scientific committees, who can measure the wisdom and good sense of his counsel, his generous and disinterested devotion, and the charm and geniality of his manner.

He was always ready to assist important astronomical work with his purse and his influence. Many Fellows of the Society will remember the admirable *soirée* which, as President, he gave to the Society, at his own expense, at Willis's Rooms, on January 17, 1866. In 1876 he showed his opinion of the value of Mr. Gill's proposed expedition to Ascension by offering to contribute a large sum towards it, if the funds could not be obtained from other sources; and more recently at the meeting of the Council of this Society, when it was proposed to apply for a Government grant for some extensive lunar computations, Mr. De la Rue privately urged the writer of this notice not to delay putting the work in hand, as he would advance the money.

By these characteristics of a generous nature, as well as by his masterly power, he won for himself the respect, the honour, and the devotion of all who knew him, and made his name illustrious among men.

He had been in feeble health for some time, but after a short illness from an attack of pneumonia, he died on April 19, 1889 at the age of 74.

Mr. De la Rue was elected a Fellow of this Society on March 14, 1851. He was one of the honorary secretaries from 1855 to 1862. In 1862 he received the gold medal of the Society "for his astronomical researches, and especially for his application of photography." He was President from 1864 to 1866, and from that time till his death was nearly continuously a member of the Council. He was elected to the Royal Society in 1850. The list of honours he received is a long one. Oxford conferred upon him the degrees of M.A. and D.C.L. In 1864 he received a Royal Medal from the Royal Society "for his observations on the total eclipse of the Sun in 1860, and for his improvements in astronomical photography." He was for many years President of the London Institution, from which he retired in 1878, and became Secretary of the Royal Institution in succession to Mr. Spottiswoode, who was elected President of the Royal Society.

This post Mr. De la Rue resigned in 1882. In 1872 he was President of Section A of the British Association. He was one of the founders of the Royal Microscopical Society. He was a corresponding member of the French Académie des Sciences for the department of astronomy; also of the Imperial Academy of Sciences, St. Petersburg, the Philomathic Society of Paris, the Royal Society of Upsala, the Society of Agriculture and Commerce, Caen, the Society of Natural Science, Cherbourg, and the Berlin Chemical Society. Three foreign Orders had been conferred upon him—Commander of the Legion of Honour, Commander of the Order of St. Maurice and St. Lazare, and Knight of the Order of the Rose, Brazil. Mr. Warren De la Rue retired from the firm of Thomas De la Rue & Co. at the end of 1880. E. B. K.

Harry Savile Ward Evans was born at Torquay on January 18, 1851. He was the younger posthumous son of William Bertram Evans, M.P. for Leominster, and Jane his wife, of Forde Abbey, Dorset, and Wimbledon Park House.

He was educated at Eton and Trinity College, Cambridge, where he graduated in the Moral Sciences Tripos in 1872. He was called to the Bar at the Inner Temple, but never practised. While at Trinity he was captain of the Cambridge University Volunteer Corps, and devoted great attention to rifle-shooting, and was for some years a member of the "English Eight" team at Wimbledon, and also of the British team when they competed in the United States against the Americans.

For the last seven or eight years he spent the greater portion of his time on a property he had acquired at Gulf Hammocks, Florida, U.S.A. He died in Paris, after a very few days' illness, on September 10, 1889.

He was elected a Fellow of this Society March 12, 1875.

Charles Hood was born in 1805, and was the son of an iron-founder in Blackfriars. For many years after his father's death he and his brother carried on the business, from which he retired some time ago.

Mr. Hood attained considerable eminence in practical science. His researches into the chemistry of the combustion of coal gained for him the silver medal of the Society of Arts. He was consulted by the Government on the ventilation and warming of the new Law Courts, when, however, the work had proceeded too far to allow of his suggestions being adopted. His treatise on ventilation and warming by hot water is the standard work upon the subject. For this he was awarded the Telford Medal by the Society of Engineers. At the time of his death he was nearly, if not quite, the oldest Fellow of the Royal Society in date of election. He was one of the founders of the British Home for Incurables (chairman from 1861 to 1866), to which

he was a generous donor. He also took an active interest in the management of King's College and Westminster Hospitals.

He was elected a Fellow of this Society January 11, 1833.

Robert Stirling Newall was born in Dundee on May 27, 1812. Though engaged in commercial business practically the whole of his life, his interests and talents were obviously of a kind that would have made him excel in purely scientific work, had the opportunity for the necessary early training and the external conditions presented themselves. He had a very keen power of observation, unusual patience and perseverance in research, a quiet persistence in following up a line which he knew to be correct in spite of prevalent opinion, and a great confidence in experimental methods. It was an opportunity for experimental work, afforded by Mr. Robert McCalmont, that induced him to give up work in Dundee, where his father's influence had gained him employment in a mercantile office. He came to London, and undertook for Mr. McCalmont experiments on the rapid generation of steam, and turned his mind to various other subjects of an experimental nature.

Always quick in devising mechanical arrangements, he readily seized upon a suggestion made by a friend who was studying mining in Saxony, and wrote that wire ropes of reasonable and efficient construction were greatly needed to take the place of the rough bundles of wire then used in the mining operations. Mr. Newall discovered the essential points in the construction of a good wire rope, and invented machinery to carry out the necessary operations.

In a short memoir in which the chief interest will be centred in astronomical subjects, the reference to Mr. Newall's interest in submarine telegraphy must be very brief, though he was occupied with the matter for at least fifteen years of a very active life. He received some of the first gutta-percha that reached this country; he suggested the wire-rope casing for the insulated telegraph lines; he constructed most of the first submarine cables, and personally took part in the laying of many of them.

In all the ordinary activity of his life between the years 1849 and 1865, when he was personally superintending the construction, testing, and laying of the cables, he still had time and inclination for numerous distinct pursuits, chief amongst them being astronomy. There exists a series of drawings of the sun, made by Mr. Newall and continued by him through the years 1848–1852. He was married on February 14, 1849, to the youngest daughter of the late Mr. Hugh Lee Pattinson, F.R.S. Doubtless it was in great part the intimate connection with Mr. Pattinson following his marriage that kept Mr. Newall's scientific interests alive in these busy years. Astronomy was one of the many subjects in which they found common ground and took practical interest. Mr. Pattinson had a $7\frac{1}{4}$-inch equatoreal by Cooke of York: this was a large glass in those days, when a 15-inch was the largest

refractor in existence. It was this telescope that Mr. Pattinson put at Professor Piazzi Smyth's disposal for his Teneriffe expedition.

The possibility of the construction and mounting of very large refractors was a subject of very frequent deliberation between Mr. Pattinson and Mr. Newall. It was only after Mr. Pattinson's death—he died in 1858—that unexpectedly the realisation of their dreams became possible. Mr. Newall saw in the Exhibition of 1862 the rough discs of crown and flint glass exhibited by Messrs. Chance, of Birmingham, and after the exhibition he acquired them, and they were transferred to the workshop of Messrs. T. Cooke & Sons, of York. The rough work of grinding and preliminary polishing had proceeded far enough to show the worth of the glass, and the agreement as to the finishing and mounting was completed in September 1863. The finished object-glasses were seen at the meeting of the British Association at Newcastle in 1865, but there were innumerable delays in the completion of the mounting, and it was not till July 1871 that Cooke could say the 25-inch equatoreal was finished. Mr. Newall designed and devised many of the arrangements himself, and helped, urged, and pressed Cooke to finish the work quickly; but when finally the telescope was completed, the plans originally made for its destination were no longer realisable. The telescope and observatory remained in the garden at Ferndene, where it had been set up in order that it might be completely put together before it was moved to a southern climate.

Of the success of at any rate one part of his experiment he was well aware from his own observations with the completed telescope. But had he been no observer himself, external testimony from the best sources would soon have convinced him.

The long delay in the completion of the instrument, which Cooke undertook in 1863 with the promise of finishing within twelve months, was a great disappointment and vexation to Mr. Newall; the more so as in those years of delay his business engagements became of a kind that would not permit him to leave England for any length of time. He scarcely needed the employment of an observer for several years to convince him that the climate of Gateshead was wholly unsuited, or rather impossible, for astronomical observations, and it was out of the question to move an incomplete instrument to a distant country, however favourable, even had his circumstances permitted. But he did not lose sight of his original purpose, and, doing all in his power to secure the completion of his first intentions, he made not one but several offers of his telescope in quarters where he expected the offer would be readily accepted. In 1875, when there was talk of the formation of a Physical Observatory, he had offered the loan of his telescope for application to the development of Physical Astronomy. The reading of *Six Months in Ascension* roused old longings in him again,

and one result following on it was the offer of the telescope and dome in 1879 for Mr. David Gill's use for seven years at the Cape of Good Hope. The circumstances which led to this offer being declined are already recorded in the *Monthly Notices*.* In the last weeks of his life he returned again to his efforts to secure success for his experiment, and on March 2 of last year (1889) proposed to give his telescope to the University of Cambridge, with a view to its being devoted to the study of Stellar Physics.

Mr. Newall was active in local matters, being Mayor of Gateshead in 1867 and again in 1868, an alderman of the borough, and Justice of the Peace. In 1876 he became a representative of the borough on the River Tyne Commission. He became a Fellow of the Royal Society in 1875, a member of the Institute of Mechanical Engineers in 1879, and in 1887 he received the honorary degree of D.C.L. at Durham University. He died in the 77th year of his age, on April 21, 1889.

He was elected a Fellow of this Society May 13, 1864.

Stephen Parkinson was born at Keighley, in the West Riding of Yorkshire, in the year 1823. He received his early education privately, and was subsequently elected to a sizarship at St. John's College, Cambridge, which in due course was changed for a foundation scholarship, as it was evident that he was a student of unusual diligence and ability. In the Mathematical Tripos of 1845 Mr. Parkinson came out as Senior Wrangler, and when it is remembered that the second place was filled by Sir William Thomson, it is plain that his work must have been of more than ordinary excellence. In the competition for the Smith's Prizes, Sir William Thomson asserted his unusual gifts, but Mr. Parkinson easily distanced all others for the second prize.

After this achievement Mr. Parkinson was elected to a fellowship of his college, and settled down to private teaching. He eventually succeeded the Rev. J. B. Mayor as tutor, and to this post, with a lectureship attached, he devoted himself for twenty years. Ordained at Ely upon his fellowship, Mr. Parkinson proceeded B.D. in 1855, and D.D. in 1868. The *Cambridge Review* states that, "As a lecturer he was distinguished by unusual lucidity of exposition, and he published an *Elementary Treatise on Mechanics*, and a *Treatise on Optics*, which had wide vogue among students. As a tutor Dr. Parkinson is remembered by his pupils for his excellent business qualities, especially his care not to spare any trouble in giving explanations by assuming that his pupils already were perfectly acquainted with the matter in hand; but still more for his frankness and kindness of heart." Among his college pupils were four senior wranglers, Moulton, Pendlebury, Ward, and MacAlister.

* Vol. xl. p. 236.

Dr. Parkinson for a short time acted as President of his college. He examined for the Mathematical Tripos in 1849 and 1852, and was on the Council of the Senate more than once. He was a Fellow of the Royal Society, and was elected a Fellow of this Society March 11, 1853.

Stephen Joseph Perry was born in London on August 26, 1833, and was the son of Mr. Stephen Perry, a member of a well-known firm in Red Lion Square. He received his early education at Gifford Hall School, and then went to France to study at the college at Douay, where he was so successful in his mathematical work as to carry off the first prize. From Douay he proceeded to the English College at Rome for theological training, as he was destined for the priesthood, and in 1853 he entered the Society of Jesus.

It was in 1856 that Father Perry first came to Stonyhurst to go through the usual course of mental philosophy and physical science. His special aptitude for mathematics was soon perceived, and in the same year he was appointed to assist the Rev. A. Weld, who was then Director of the Observatory.

In 1858, on matriculating at the London University, he went up for mathematical honours, taking the sixth place. After this he was sent to London for a year to study under Professor De Morgan, and then for another year to Paris, where he attended the mathematical lectures of Liouville, Delaunay, Serrat, Cauchy, and Bertrand.

In the autumn of 1860 he returned to Stonyhurst, being appointed Professor of Mathematics and Director of the Observatory, as successor to Father Weld, who had held that position for many years. In the autumn of 1863 he left to complete his theological course at St. Beuno's College, in North Wales, where he was ordained priest in 1866; and when all his studies were completed he came back finally to Stonyhurst in 1868 to resume charge of the observatory, which he continued to direct until the day of his death.

The first important scientific work Father Perry undertook, was in the autumn of 1868, when he spent the vacation in making a magnetic survey of the west of France, in which he was assisted by the Rev. W. Sidgreaves, S.J. The instruments employed were those in constant use for the monthly observations of the magnetic elements at Stonyhurst. Complete sets of observations of dip, declination, and horizontal force were taken at fifteen different stations, and the elements reduced to January 1, 1869, the secular variations being obtained by comparison with Lamont's observations made ten years previously.

In the following year this survey was continued and extended to the eastern part of France, the months of August and September being devoted to it. Complete sets of observations were made at twenty-one stations, and the elements reduced to the same epoch. In both series two sets of observations were made

at Paris. Thus the magnetic elements of thirty-five different stations, well distributed over France, were determined by the same observers with the same instruments.

Father Perry's attention had been directed to the unsatisfactory character of the magnetic elements in Belgium, and he considered that a new series of determinations was rendered necessary in consequence of previous observers having chosen very few stations in that country, and especially as the curvature of the isodynamics and isoclinals in Lamont's maps indicated some very considerable disturbing cause. In 1871, therefore, he, assisted by Mr. W. Carlisle, undertook a new magnetic survey, when complete sets of observations were made at twenty different stations.

The result was to indicate that the coal measures, which stretch completely across the south-eastern portion of the country, exercise a strong disturbing influence, so much so as to completely mask the normal direction of the lines.

The results of these magnetic surveys were all published in the *Philosophical Transactions*.

In 1870 Father Perry was chosen as chief of the expedition to Cadiz to observe the total eclipse of the Sun, the results of which he communicated in a paper published in the *Monthly Notices*.

In 1872 he commenced regular observations of the phenomena of *Jupiter's* satellites, employing the 8-inch Troughton and Simms Equatoreal. These have been continued to the present date, and, with the exception of the period 1875–1877, when there existed unavoidable hindrances to the prosecution of the observations, they form a fairly connected series, which have been published in the *Monthly Notices*.

In 1874 Father Perry was appointed to the command of the important expedition to Kerguelen Island to observe the transit of *Venus*. It is unnecessary to refer particularly to the observations made on that occasion, which have all been published in the official account, and fully discussed in the *Monthly Notices*. But he has recounted his experiences of the whole expedition in some graphic and delightful "Notes of a Voyage to Kerguelen Island to Observe the Transit of *Venus*, December 8, 1874," published in the *Month and Catholic Review* in 1876.

He, with the Rev. W. Sidgreaves, his companion in the French magnetic work, left England in the latter part of June 1874 and arrived at the Cape of Good Hope July 20, where all the members of the party were assembled. Various accidents and hindrances occurred which prevented the expedition leaving Cape Town till September 18. The voyage to Kerguelen, or Desolation Island, in H.M.S. "Volage" was an eventful one from the heavy weather and exceedingly rough sea that were experienced. Father Perry was throughout life a martyr to seasickness, which never left him so long as he was on board ship, but his narrative contains no word of his own sufferings in a

voyage which must have been full of pain and discomfort, and, indeed, not without peril.

Few persons have probably realised what was involved by going to this island to observe the planet *Venus* pass across the Sun's disc. The desolate situation, almost 3,000 miles away from any habitable spot; the dreary aspect of an island of rock and lake and bog, without man, or beast, or tree to break the monotony of its loneliness; and, most of all, the fearful approach through mist and storm, with waves the greatest in the world, and winds blowing a gale for five days out of every seven: and yet it was this cheerless island that Father Perry and his companions inhabited from October 8 to the 26th of the following February, with weather in which, he says, they were never free from the danger of a heavy fall of snow, even at midsummer, and with a wind which seldom failed to blow fully half a gale in the course of forty-eight hours. On the eventful December 8 the sky was very hazy and Father Perry's observations of the ingress of *Venus* were in consequence very imperfect; but as egress approached the Sun cleared a little, without, however, being brilliant, and he was able to secure both contacts. His work, however, was not over. Sir George Airy had pointed out to him, as he did to the meeting of this Society in November 1874, the necessity for an absolute determination of longitude at Kerguelen. This meant one hundred double observations of lunar altitude, or azimuth, and thirty transits of the Moon over the meridian. When we learn from Father Perry's "Notes" that up to December 8 only five transits and a proportionate number of azimuths had been secured, we may well admire the enthusiasm and the high sense of duty that impelled him and his party to settle down for a further twelve weeks' work in this inhospitable clime; that being the utmost time it was calculated to be prudent to stay, on account of the stock of provisions; and even that accompanied with the prospect of a home journey of many thousand miles upon half rations. As he modestly puts it, "We must not deny that there was a little grumbling, but the work was done, and, we hope, thoroughly." On the homeward voyage a cyclone, which flooded everywhere, with wind blowing a hurricane and the ship rolling at times more than 45°, was one of the most perilous trials he experienced.

But these discomforts and hardships seem only to have inspirited Father Perry to devote himself in the future to like expeditions, for in 1882 he again took charge of an expedition to the south-west coast of Madagascar to observe the transit of *Venus*. On this occasion he was accompanied by Father Sidgreaves, who had been his companion at Kerguelen, and by Mr. Carlisle, an assistant at the Stonyhurst Observatory. The party left England on August 29 and arrived at Madagascar October 22 in H.M.S. "Fawn." The insecurity on the main island made Father Perry select the small island of Nos Vey for his observing station. Nos Vey is a heap of sand, three-quarters of

a mile in length by one-quarter in breadth, surrounded by a coral reef, and inhabited by French and English traders, with about sixty native families from the mainland. On the south point of this sandbank he erected his instruments. On the day of the transit, notwithstanding a high wind and showers of fine sand, which fell over the instruments, satisfactory observations of internal contact at ingress were secured by all the observers. The particulars of these observations have been published in Mr. Stone's official report.

In 1886 Father Perry went out to the West Indies with the British expedition to observe the total solar eclipse of August 29 in that year. His station was at Hermitage, on the island of Carriacou. For the observation of this eclipse he took out the $5\frac{1}{2}$-inch equatoreal by Alvan Clarke, which had formerly belonged to the Rev. T. W. Webb. He devoted himself to spectroscopic observations, the report of which has been published in the *Philosophical Transactions*.

In 1887 he was nominated by the Council as a representative of this Society, to observe the solar eclipse of August 19. For this purpose he accepted the hospitable invitation of Professor Bredichin, and proceeded to the town of Pogost, on the Volga, but on account of the bad weather he was unable to secure any important observations.

Soon after his return from Kerguelen in 1875 Father Perry had turned his attention to solar physics, and had inaugurated a series of solar drawings and measurements of the chromosphere, in which he was materially assisted by the special aptitude for drawing such objects displayed by one of his assistants, Mr. McKeon. This work has been continued uninterruptedly since 1879, and includes a careful drawing of the solar surface on every available occasion (made by projecting the image on a screen), and also a complete measure of the Sun's chromosphere, to which, in 1882, a spectroscopic examination of Sun-spots was added. Many of the results have been published in the *Monthly Notices*, in astronomical journals, and in the published annual volumes of the Stonyhurst meteorological and magnetical observations.

In an interesting paper contributed to vol. xlix. of the *Memoirs* of this Society, Father Perry has discussed the correctness that can be attained by solar drawings, from an examination of Greenwich photographs and Stonyhurst drawings made on the same days. In this paper he calls attention to the curious fact that whereas the mean daily spot area in the photographs is in excess of that in the drawings, the reverse is the case with the faculæ, which in the drawings are largely in excess. An account of the Stonyhurst solar work formed the subject of Father Perry's lecture to the Royal Institution last May.

Up to the time of his leaving England on his last fatal expedition, it was his full intention, at the earliest possible time, to prepare a work embodying a complete discussion of the results derivable from the solar and magnetic observations he had

carried out at Stonyhurst. This work had been planned out with the object of throwing light upon theories of Sun-spot formation, and on solar physics generally, and also to find, if possible, a clue to the nature of the connection between Sun-spots and terrestrial magnetism. Before leaving Stonyhurst last November he instructed his assistant to prepare the materials and be ready when he came back to commence a systematic study of the life history of each group of spots recorded in the Stonyhurst drawings, and also to investigate all the spots for each year studied collectively on a chart. This work was intended to be exhaustive of the material he had accumulated, which he considered might be sufficient to throw important light on the subject of the proper motions in spots, on the connection between spots and faculæ, the recurrence of spots in the same heliocentric position, and many other questions of solar physics. The remarkable observations of veiled spots which Father Perry brought before the Society in January 1888 indicate that the method of projection adopted is capable of furnishing results of considerable interest and value. It is a serious loss to astronomy that his untimely end has prevented so hopeful an investigation from being conducted under the auspices of the author and originator of the work.

In the early part of 1889 the Council invited Father Perry to take charge of the Royal Astronomical Society's expedition to French Guiana to observe the total solar eclipse of December 21–22, 1889. He at once, with the enthusiasm that was characteristic of his nature, accepted the confidence that was placed in him, and from that time till he left England in November spared no effort in his preparations to fulfil his mission in the most satisfactory manner to astronomy and to the Society.

The programme of the operations for observing the eclipse has already been published in the present volume, and we need not here make further reference to it; but the story of his last fatal expedition is too romantic not to be recorded in some detail.

Father Perry, accompanied by Mr. Rooney, one of his colleagues at Stonyhurst, left Southampton on November 14, in the Royal Mail s.s. "Tagus," and arrived at Barbados on November 26. On December 2 he left Barbados in H.M.S. "Comus," Captain Atkinson, and arrived at the Isles du Salut, near Cayenne, on December 7, anchoring at "Royal Island." During the voyage the weather was very rough, and he suffered severely from sea-sickness. Notwithstanding the resulting prostration, he insisted upon landing the evening of his arrival, in order to examine the site for the observatory, and to introduce himself to the French authorities, from whom he received the greatest courtesy and assistance.

He took up his quarters at the military hospital, where two very good rooms were placed at his disposal by the Commandant. It was soon discovered that the sanitary arrangements of the

whole island were very bad, and, notwithstanding the urgent and repeated request of Captain Atkinson that he would sleep each night on board the "Comus," he insisted upon passing the night at his quarters. Had he acceded to that request, it is probable his life would have been spared; but his fear of giving trouble to others, his high sense of duty, and his conscientious desire to accomplish his work in the most successful manner, were with him paramount considerations over any personal discomfort or danger. On December 20 it was discovered that he was in seriously bad health; indeed, his companions considered him in feeble health all the time he was on the island. At last this forced itself upon him so much that he acknowledged to Captain Atkinson that he felt himself to be unfit for the work.

The rain, which had set in on the 18th, caused the weather to be very unhealthy. A large number of convicts on the island were ill with dysentery, and deaths were occurring at the rate of four or five a day. On the 20th he complained of being very ill, but the night clearing up after the heavy rain, he rashly determined to remain at the observatory all night to secure some trial photographs. He worked on till 3 A.M., and when his men retired on board the "Comus," he merely lay down in a hammock in the tent, so as to be ready to take the position of the Sun at rising just before 6. Doubtless the fatal chill was here received, for the same night, December 21, he was very ill with cramp and diarrhœa; so ill, indeed, that it was feared he could take no part in the observation of the eclipse; but the enthusiasm and self-denying spirit that had carried him through so many previous difficulties, were not yet to be quelled by bodily ailment, and on the morning of the eclipse he managed, with the assistance of a seaman, to walk the rough and difficult half-mile from his quarters to the observatory, and declined to allow himself to be carried on a stretcher. He at once took his place at Mr. Common's large photographic instrument, and conducted the whole proceedings.

Up till about twenty-five minutes before totality a heavy black cloud had completely obscured the Sun, but this cleared off at the critical moment, and allowed him to make, in the most satisfactory manner, all the observations which he had travelled so far to accomplish. The success of the observations seemed to give him new life; he was alert and self-possessed, and was really much better. He stated that he had never conducted so successful an observation of the Sun's eclipse before. He then asked Captain Atkinson to call for three cheers for the successful observation: "I cannot cheer," he said, but he waved his helmet. After uttering these words, which convey so much that is touching and pathetic, the effort of strength he had called up to nerve him to the fulfilment of his mission was soon dissipated, and he rapidly became dangerously ill. Of the last moments of his life there is little to tell. On the afternoon of the eclipse he was taken on board the "Comus," and put to bed

in the captain's cabin, suffering from the most virulent form of dysentery. On the 26th he was better, and the "Comus" at once proceeded with all despatch for Demerara, but on that night gangrene of the lower bowel showed itself, and Father Perry died at 4.20 P.M. on the 27th. When told he was dying, he calmly sent for Mr. Rooney, and gave him full directions about everything connected with the eclipse, told him where his notes were, and left nothing undone. He was enthusiastic to the last, and in his wanderings just before death he rehearsed the operations which took place at the observation station during the eclipse. His body was landed at Demerara on December 28, where it was at once interred in the old Catholic cemetery.

Thus died Father Perry, through a devotion to duty which will always ennoble his name, and rank him in the long list of those who have made allegiance to the call of duty their supreme guide: "Not only religion and war, but even astronomy has its heroes."

At their meeting on January 10, 1890, the Council of this Society recorded in their minutes the following resolution, which was passed unanimously: "The Council, having heard with the deepest regret of the death of the Rev. S. J. Perry while on the Society's expedition to observe the total eclipse at the Salut Isles, desire to put on record their sense of the great loss which astronomy has suffered by the death of so enthusiastic and capable an observer, and to offer to his relations and to his colleagues at Stonyhurst the expression of their sincere sympathy and condolence on this sad event."

As a professor, Father Perry's chief characteristics were the extreme care he took in the preparation of his lectures, and the earnestness he threw into his work. What he undertook, that he did as thoroughly as lay in his power, whether it were astronomical observations, or teaching mathematics, or playing games with the boys at Stonyhurst. In this respect his characteristic was concentrativeness, coupled with a charming, simple earnestness that captivated respect and esteem. Loyalty to science and to his college were part of his nature, and a word at the expense of either roused him at once. As a public lecturer on astronomical subjects he was very effective and popular. He delivered lectures at the Royal Institution, in many places in the north of England, and on one occasion, in 1887, he lectured in French at Brussels. His last lecture was to the crew on board the "Comus," and his last sermons were preached in French on December 8 and 15 to the convicts at the Salut Isles. Thus his life passed simply and laboriously, without pretence or affectation, and, great as was his devotion to science, his desire was still greater to do his duty in the state of life he had chosen, in whatever direction that duty might be appointed for him.

Father Perry was elected a Fellow of the Royal Society in 1874, and was made a member of its Council last November. In 1886 he received the honorary degree of D.Sc. from the

Royal University of Ireland. He was a member of the Royal Meteorological, the Physical, and the Liverpool Astronomical Societies, of which last he was President. He was also a member of the Accademia dei Nuovi Lincei, of the Société Scientifique de Bruxelles, and of the Société Géographique d'Anvers. For several years he served on the Solar Physics Committee and on the British Association Committee for comparing and reducing magnetic observations.

He was elected a Fellow of this Society April 9, 1869, and served on the Council for several years, and in December last he was proposed by the Council as one of the Vice-Presidents for the ensuing year. E. B. K.

George Elliot Ranken was born in the year 1828, and was educated at Eton and Oxford. His career at Eton was brilliant and exceptionally successful, and at the age of eighteen he entered University College, Oxford, on the foundation, having won the scholarship the previous year. His tutor at Oxford was the late Dean Stanley, who often prophesied great things of his future. Soon after taking his degree he became a student at the Inner Temple, and then entered the War Office as private secretary to Sir Edward Lugard. On resigning this position Mr. Ranken settled in Rome, where for some years he was attached to the Papal Court, having been appointed a Privy Chamberlain by Pope Pius IX. In the year 1871 he returned to England and became editor of the *Tablet*, a position which he held until about five years ago, when ill-health compelled him to resign it.

In the year 1859 Mr. Ranken married Georgina Elizabeth, daughter of the Rev. H. W. Buckley, Rector of Hartshorne, Derbyshire, by whom he leaves two children, a son and a daughter.

Mr. Ranken was a man of more than ordinary accomplishment. His early training and the reading of his lifetime had left him with a memory singularly well stored, and with the more important results of an habitual retentiveness. His love for literature was liberal and most intelligent, and he fed it on the works of many languages, his linguistic talent being remarkable. To his familiarity with the modern literature of Europe he added a ripe and an accurate scholarship, which made his opinion upon any question connected with the classics specially valuable. In the problems of astronomy he found a resource and a pleasure which even his failing health never seemed to impair. But it was only those who knew Mr. Ranken well—perhaps only those who lived in habitual and professional intercourse with him—who ever fully realised how gifted he was and in how many ways.

He was elected a Fellow of this Society January 13, 1882.

George Francis Riddiford, who died at Barnwood Lodge, near Gloucester, on December 6, 1889, was born at Gloucester in

1841, and subsequently articled to Messrs. Wilton, solicitors, of that place. When admitted, he was received into the firm as a partner, and ultimately became its sole representative. He had a very extensive practice of the highest class, and he held many valuable public appointments, being Registrar of the County Court; County Treasurer; Clerk of Indictments; and Clerk to the Income Tax Commissioners, as well as of many public companies. In all these capacities he brought to bear a very sound judgment, a wide knowledge, and unswerving integrity. He devoted considerable attention to scientific pursuits, and possessed large scientific knowledge, especially upon the subject of astronomy, the study of which occupied much of his leisure time. He built an observatory in his grounds, and fitted it with a 12-inch reflecting telescope by Browning, a transit instrument, sidereal clock, and other requisites.

It is interesting to know that his observatory and all its contents, together with a full set of spectroscopic apparatus, have been presented by his widow to the Gloucester School of Science, in which he took a keen interest, and where it is hoped that they will serve to promote the study of astronomy.

He was elected a Fellow of this Society January 11, 1878.

George West Royston-Pigott was the youngest son of the Rev. Solomon Pigott, for many years Rector of Dunstable. He entered the University of Cambridge in 1838 and graduated as twenty-second Wrangler in 1841, his mathematical tutor being the Rev. W. R. Griffin, and soon after taking his degree he was elected to a Fellowship at Peterhouse. He continued in residence at Cambridge for several years longer, pursuing the study of medicine, and took the degree of M.D. there in 1851. Dr. Royston-Pigott attained distinguished success as a physician during his subsequent residence at Harrogate, but after some years he retired from the active duties of his profession. Meanwhile he never relaxed the favourite studies which led him into the domains of astronomy and the world of marvels revealed by the microscope. He was a mechanician of the first order, and many details of his costly and beautiful instruments were wrought by his own hands or carried out under his direction.

Finding himself at one time baffled by the imperfections of even the best microscopic objectives, he set himself to investigate the causes of the residuary aberration and to devise means for correcting it. Here his knowledge of mathematical optics told. By means of corrections of his own devising, applied to the highest powers of the instrument, he succeeded in resolving objects of hitherto invincible difficulty, and pointing out to other observers most interesting lines of work. It was in recognition of his eminent service to science in this respect that he was, in 1873, elected Fellow of the Royal Society. Shortly after this a Fellowship in the Royal College of Physicians was offered to him, which, however, having then retired from medical practice,

he thought it right to decline. The record of Dr. Royston-Pigott's work is not contained in any great production, but lies scattered in numerous papers published in the Transactions of the Royal and other societies, and a record more abiding and more useful perhaps remains in improvements in various scientific instruments and more refined methods of research suggested by him. His ideas and discoveries were freely made public from time to time for the benefit of all who might find them useful.

He died at his residence at Eastbourne, September 14, 1889.

He was elected a Fellow of this Society, February 12, 1869.

Gaetano Cacciatore was born at Palermo on March 17, 1814. He was the son of Catarina Emanuela Martina and Nicolo Cacciatore, the distinguished Director of the Palermo Observatory and the successor of the illustrious Piazzi.

Gaetano Cacciatore received his education at the Istituto Nautico and the University of Palermo, where he pursued his mathematical studies until the year 1834. In the following year he was placed under the guidance of his father as Second Assistant at the Observatory of Palermo, and in 1839 he succeeded to the position of First Assistant. On the death of his father in 1841 he undertook provisionally the direction of the Observatory, which position he held until the year 1843, when he was appointed Professor of Astronomy at the University of Palermo and Director of the Observatory.

In 1842 he commenced the publication of the *Annuario* of the Palermo Observatory, which contained astronomical ephemerides, meteorological observations, &c.

In 1848 he took an active part in the Sicilian revolt, and became a Deputy to the Sicilian Parliament, where he assisted in decreeing the downfall of the Bourbons. On the restoration of the reigning family, in 1849, Cacciatore refused to retract his action, and consequently he was banished from Palermo, and the Chair of Astronomy became vacant.

Cacciatore, being thus deprived of his observatory and astronomical work, took up the profession of engineer to the sulphur mines of Grotta Calda, for which he was much indebted to the generosity of the Prince of Sant Elia.

On the liberation of Sicily by Garibaldi in 1860, he was recalled to his former position at the Observatory and to the Professorship of Astronomy at the University.

Notwithstanding the long absence of ten years from his observatory and astronomical pursuits, his enthusiasm for his favourite science led him to devise means to raise the Palermo Observatory to a higher and more important position.

In 1863 he mounted under a large dome the fine equatorial refractor by Merz, of 9·8 inches aperture and 14½ feet focal length. In the same year he began the publication of the *Bullettino Meteorologico* of the Palermo Observatory, which up to 1872 contained astronomical notes and memoirs; after that time

this was discontinued, and the astronomical researches of the Observatory appeared in the *Memorie della Società degli Spettroscopisti*, then published by M. Tacchini at Palermo.

In 1879 Cacciatore obtained from the Government a more complete reorganisation of the Observatory into the three sections of Astrophysics, Meridian Astronomy, and Meteorology; each section having a staff of two assistants and a servant.

In 1880 he founded the Meteorological Observatory, which was established in an excellent position in the district of Valverde, about $1\frac{1}{2}$ kilometre west of the Observatory, and supplied with the necessary instruments.

In 1882 he undertook another series of publications—viz., the *Publicazioni* of the Palermo Observatory, which contains the more important researches of the three sections referred to above. He published three volumes and began the fourth, which his death unfortunately prevented his completing. This has since been published by Signor Ricco, the present Provisional Director of the Observatory.

Professor Cacciatore was vice-president of the Italian commission for the observation of the solar eclipse of 1870, and was instrumental in organising the observing stations and publishing the results in a volume which appeared in 1872 under the title *Eclisse Totale di Sole del* 1870. He was President of the Faculty of Mathematical, Physical, and Natural Sciences for nine years, and for many years he was Director of the Engineering School at Palermo. He also held an important position in the municipality and the province of Palermo. Among other distinctions, Professor Cacciatore was a Commander of the Order of the Crown of Italy and an officer of the Order of St. Maurice. He was a member of the Italian Spectroscopic Society and of the Royal Academy of Palermo.

He died on June 16, 1889, to the great regret of his colleagues and friends, who loved him much for his rare goodness of heart and his exquisite courtesy of manner.

He was elected a Foreign Associate of this Society December 13, 1844.

Lorenzo Respighi was born at Cortemaggiore, Piacenza, on October 7, 1824, and was the son of Luigi Respighi and Giuseppina Rossetti. He studied at Parma and at the University of Bologna, where, in 1847, he took his degree in philosophy and mathematics. In 1849 he was appointed Professor of Mechanics and Hydraulics at the University of Bologna. Two years afterwards he became Professor of Astronomy, and in 1855 was appointed Director of the Observatory at Bologna.

Most of Professor Respighi's voluminous scientific work is published in the transactions of the Istituto di Bologna, the Accademia dei Nuovi Lincei, and the Accademia dei Lincei. His earliest publications were mainly meteorological.

In 1862 and 1863 he discovered three comets, the observa-

tions of which were published in 1865, in which year he was appointed Professor of Astronomy at Rome and Director of the Observatory of Campidoglio.

Among the astronomers who have devoted themselves to the spectroscopic study of the solar prominences, Professor Respighi stands in the foremost rank. In 1869 he commenced the series of observations which has made his name celebrated in this branch of research. Pursuing his observations with extraordinary assiduity, he in less than three years sketched and mapped more than 8,000 prominences. He systematically and assiduously continued these researches for more than fifteen years, and he thus accumulated a mass of observations which are of high importance to the advancement of our knowledge of solar physics. His results are contained in some nine or ten papers published in the transactions of the academies mentioned above.

From 1874 to 1882 he made a very extensive series of observations of the Sun's diameter, and published two papers on the alleged variation in that diameter.

To meridian astronomy Professor Respighi has contributed three catalogues of the mean declinations of stars of the first to the sixth magnitudes, made with the Ertel Meridian Circle which was given to the observatory by Pope Pius IX. The first, in 1877, is a catalogue for the epoch 1875·0 of 285 stars within the parallels $+20°$ and $+64°$. The second, published in 1880, supersedes the first, and contains 1463 stars within the same parallels and for the same epoch. This paper contains an exhaustive determination of the latitude of the observatory and a comparison of the catalogue with Auwers' Fundamental and the Greenwich Nine-year Catalogues. The result is to show that Respighi's declinations are of a high value. In 1884 he published his third catalogue of mean declinations, for the epoch 1880·0, of 1004 stars comprised within the parallels $+0°$ to $+20°$ and $+64°$ to the pole.

Numerous other contributions to astronomy by Professor Respighi are to be found in the publications of several of the Italian academies which we cannot more particularly refer to here.

He died at Rome on December 10 of the past year. He was elected a Foreign Associate of this Society November 8, 1872.

Ernst Wilhelm Leberecht Tempel was born on December 4, 1821, at Nieder-Kunersdorf, near Löbau, in the kingdom of Saxony. His parents were people in poor circumstances, and so he received but a scanty education, which in after years he lost no opportunity of improving. When about twenty years of age he went to Copenhagen, where he worked for about three years as a lithographer, and where his lively manners and his taste for music and art acquired for him many friends, some of whom he never lost sight of. After leaving Copenhagen he went for some time to Christiania, and his roving spirit then brought him to

Italy, where he settled at Venice and exercised his art for many years. Having become interested in astronomy he purchased a 4-inch refractor by Steinheil, with which he began exploring the heavens. It was a great encouragement to him to persevere in this occupation (for which he had obtained leave to use the balcony of a Venetian palace), that on April 2, 1859, he succeeded in discovering a comet (1859 I), and thenceforth he remained an enthusiastic observer until his last illness. He was the first to notice (on October 19, 1859) the now well-known nebula around *Merope* in the Pleiades, the announcement of which, though confirmed by various observers with small instruments, was received with much hesitation, as the object was less readily seen with a larger aperture and higher power.

In March 1860 Tempel went to Marseilles, where he obtained employment at the Observatory, which was then under the direction of Valz. He picked up his second comet (1860 IV.) in October 1860, and also turned his attention to the minor planets, of which he in the years 1861 to 1868 discovered five. He remained attached to the Observatory till towards the end of 1861, when he settled in the Rue Pythagore, Marseilles, and resumed his work as a lithographer. But Tempel continued to show himself an indefatigable observer, and as he had only his 4-inch refractor he was naturally induced to remain faithful to the field of work in which he had first been successful—that of comet-seeking. Among the eight comets which he found while at Marseilles,* the first one of 1866 attracted great attention from its connection with the November meteors, while the second one of 1867 was found to belong to the interesting class of periodic comets of short period. It was observed again in 1873 and 1879, but in 1885 was too distant and too faint to be seen. Comet 1869 III., which was also discovered by Tempel, was in 1880 found to be periodic; it is known as Tempel's third periodic comet, and passed the perihelion in May 1886, when it was too unfavourably situated to be observed.

In January 1871 Tempel was as a German expelled from France by the Provisional Government. He went to Milan, where Professor Schiaparelli was glad to accept his services as an assistant at the Brera Observatory. There he continued observing comets, and discovered three new ones,† among which his second periodic comet (1873 II.) is remarkable as having a very short period—only a little over five years. It was observed again in 1878, but was unfavourably placed with regard to the earth both in 1883 and 1889. Tempel's observations made at Milan, chiefly of comets, were published in the Milan ephemeris for 1872 and in No. 5 of the *Pubblicazioni* of the Brera Observatory; in the latter there is a fine lithographed plate of the Pleiades with the *Merope* nebula, which he later improved

* 1860 IV., 1863 IV., 1864 II., 1866 I., 1867 II., 1869 II., 1869 III., 1870 I.

† 1871 II., 1871 IV., 1873 II.

by the addition of many minute stars, after which he republished it in the *Monthly Notices*, vol. xl.

Towards the end of 1874 Tempel left Milan to accept the post of Assistant in charge of the Arcetri Observatory, which is connected with the *Reale Istituto di studi superiori* of Florence. Having now for the first time the use of larger instruments, he thenceforth devoted himself to observations of a more systematic character, and discovered only one more comet, 1877 V. In all he had been the first discoverer of thirteen comets (counting 1870 I., which was detected both by him and by Winnecke within a few minutes), while he found four which had been detected somewhat earlier by other observers, * and one cometary object (December 29, 1871) which could not be found again.

The Observatory at Arcetri had been erected in the years 1869–1872 from the designs of Donati, but when this energetic astronomer died in September, 1873, the buildings, though externally finished, were not complete, and the mounting of the largest instrument—a refractor by Amici, of 11 inches aperture—was far from finished, so that there was neither clockwork nor graduations on the circles. The building seems also to have been badly constructed, as the walls of the meridian-room had to be strengthened in 1875 to prevent them from giving way. Nobody appears to have taken the slightest interest in the observatory after Donati's death, and for fourteen years Tempel had to struggle on, subsisting on a scanty salary, and endeavouring to do good work with a half-finished instrument. The years which Tempel had spent in comet-seeking had caused him to take a great interest in nebulæ, and, notwithstanding all the obstacles with which he had to contend at Arcetri, he resolved to apply himself to observations of these objects. He had at his disposal two instruments with object-glasses by Amici, both of which were optically suitable for observing nebulæ. One was a refractor of 9·4 inches aperture and 10½ feet focal length, roughly mounted on a portable stand, but it does not appear to have been much used, as a slight wind was sufficient to set it in motion on the sloping terrace, which was the only place where it could be used. The other refractor has 11 inches aperture and 17½ feet focal length, and is equatorially mounted under the central dome; but mounting and dome have been so badly designed that objects in altitudes less than 20° cannot be observed. Undaunted by these difficulties, Tempel collected a considerable number of observations of nebulæ. Many of his results have appeared in a series of notes in the *Astronomische Nachrichten* (vols. 90–113), from which it may be seen that a great number of objects not observed elsewhere since Sir W. Herschel's time have been examined and their places corrected, and many new nebulæ found and micrometrically observed. But, above all, Tempel devoted his attention to the

* These are: 1862 II., 1863 III., 1867 I., and 1874 II.

making of accurate drawings of the more interesting nebulæ, a pursuit for which his artistic skill and experience made him particularly fitted; while he had also the advantage of a very pure sky and an instrument of sufficient aperture and excellent defining power. A photographic reproduction of a drawing of the nebula of *Orion* will be found in a short memoir on nebulæ printed in 1885 in the *Abhandlungen der K. Böhmischen Gesellschaft der Wissenschaften* (reviewed in the *Vierteljahrsschrift*, vol. xxii.).* A list of the drawings made at Arcetri was given in the same memoir, comprising 186 nebulæ, or groups of nebulæ. It would appear that steps were taken some years ago to have these drawings published, as Tempel in 1886 sent the writer of these lines a lithographed plate, which he described as a failure, adding: "It belongs to my Roman work on nebulæ (22 plates), which unfortunately will probably never be published, as we hitherto have not found an artist capable of copying my nebulæ." It is very much to be hoped that this work may be published, together with Tempel's numerous notes and measures (with an annular micrometer) of neighbouring stars and companion nebulæ. In the beginning of 1887, when he found himself unable to observe, Tempel began to arrange and put in order his scattered notes and sketches, many of which had as yet only been jotted down on various maps, and intended to enter them all in a copy of Herschel's *General Catalogue*, interleaved with two white leaves between each two pages, but we are not aware whether he succeeded in completing this task. We trust, however, that his Italian *confrères* will not allow his work to be buried in oblivion, but that they will interest themselves in having it published in the same systematic and complete manner in which the observations of Dembowski were given to the world some years ago.

Tempel's mind, which always had been somewhat inclined to melancholy, had in Italy found peace by embracing the Roman Catholic faith. About the end of 1886 he was attacked by a liver complaint, and some months later by partial paralysis. He lingered till March 16, 1889, when death relieved him from his sufferings. His mind remained clear to the last. He was buried near the tomb of Donati, his predecessor in charge of the Arcetri Observatory.

In addition to various prizes from the Vienna Academy for his discoveries of comets, Tempel, in 1879, received the prize which every six years is awarded by the Accademia dei Lincei for some astronomical work. He was elected a Foreign Associate of this Society June 10, 1881. J. L. E. D.

* A drawing of the *Orion* nebula in 1861, drawn and lithographed by Tempel, appeared in the *Ast. Nach.*, vol. 58.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.

The Ten Year Catalogue of 4059 stars, epoch 1880, has been passed for press, and one or two copies were received before the end of the year. The large amount of work which has been done in reducing the observations to a uniform system, and in examining discordances, has been already referred to in previous Reports. It is to be further remarked that the number of stars is about double that of previous catalogues, as the following figures will show:

			No. of Stars.
Twelve	year Catalogue	1840	2156
Six	„ „	1850	1576
First Seven	„ „	1860	2022
Second Seven	„ „	1864	2760
Nine	„ „	1872	2263
Ten	„ „	1880	4059

The reobservation of Groombridge's stars, commenced in 1887, has been steadily proceeded with, though occasionally retarded by special demands, such as the observation of comparison stars used by Dr. Gill and others at the oppositions of *Victoria* and *Sappho*. The number of close circumpolars regularly observed has also been increased by the addition of 10 stars, frequently used in longitude operations. The total number of transits observed in 1889 was 5343, and of zenith distances 5142; the total number of stars observed being 1650. Of these, 244 observations were made of 41 stars for *Victoria*, and 151 of 42 stars for *Sappho*; the planets themselves being observed on the meridian 15 and 9 times respectively. Meridian observations of Sun, Moon, and planets have been regularly continued as before.

The mean error in R.A. of Hansen's Lunar Tables, with Newcomb's corrections, as deduced from 92 observations with the

transit circle in 1889, is $+0^{s}\cdot010$, which is of the same sign as all the other mean annual values since the introduction of these corrections in 1882, but smaller than any previous value. The series from 1883 is $+^{s}\cdot032$, $+^{s}\cdot021$, $+^{s}\cdot028$, $+^{s}\cdot029$, $+^{s}\cdot065$, $+^{s}\cdot079$, and $+^{s}\cdot010$.

From January 1, 1889, circumpolar stars have been observed by the galvanic method, using the R.A. micrometer to bisect the star at a moment recorded with the other hand on the chronograph. Observations of the same transit by both methods made in the later months of 1889 show that no sensible systematic change in right ascension has been thereby introduced.

The results for level and azimuth error in 1889 show that the cleaning and adjustment of the Y's in January 1888 have not interrupted the gradual settling down of the instrument, which causes a tendency to a negative level error and a positive azimuth. The range of level in 1888 was $+7''\cdot0$ to $-2''\cdot0$; in 1889, $+5''\cdot7$ to $-3''\cdot6$. The range of azimuth in 1888 was $-8''\cdot2$ to $+3''\cdot3$; in 1889, $-6''\cdot6$ to $+6''\cdot0$.

On September 26 an amalgamated copper bottom was fitted to the mercury trough used in reflexion observations, which have been thereby rendered much more satisfactory. Tremors are not nearly so noticeable, and quicky subside. From comparison of observations before and after the change, it appears that the mean difference between two bisections of the same star at the same reflexion observation has been reduced from $0''\cdot80$ to $0''\cdot56$.

Observations of the horizontal flexure of the transit circle on January 3, April 18, May 14, 1889, and January 14, January 15, 1890, gave results $+0''\cdot08$, $+0''\cdot52$, $+0''\cdot26$, $+0''\cdot05$, and $+0''\cdot28$. No correction for flexure has been applied since April 1879, this correction being virtually included in the R—D correction which for 1888 was $+0''\cdot75$ sin Z.D. The apparent correction to the nadir observation deduced from reflexion observations of stars in 1889 is $+0''\cdot072$. For the year 1888 this quantity was $-0''\cdot118$. No correction for this discordance has been applied.

Observations on the distribution of temperature in the transit circle room, by means of four thermometers suspended at different points, were continued throughout 1889. One of these thermometers (I) is close to the instrument; the others, N, S, and M, are at the north and south corners and in the middle, respectively, of the top horizontal shutter opening in the roof. An exterior thermometer (E) is just outside the north wall of the transit circle room, and another (F) is in the front court at a distance from the building. Simultaneous readings of these six thermometers were made on 350 occasions during evening observations in the years 1888 and 1889, the exterior temperature ranging from 27° to 67°. Care was taken in each case that all the observing shutters had previously been open for at least half an hour, and generally some hours, to ensure free circulation.

The results show that at the freezing-point for F the excess of readings of E, S, N, M, and I are respectively 0°·3, 1°·0, 1°·4, 2°·0, and 3°·8; and that for every 10° rise of temperature in F these differences decrease with some regularity by about 0°·30, 0°·33, 0°·39, 0°·43, 0°·66 respectively. A careful determination was made of the index errors, and the above quantities are corrected for index error; but in order to eliminate any residual index error from the difference of N and S, which is important as showing an unsymmetrical distribution of temperature, these thermometers have now been interchanged, and the observations will be continued in 1890.

Observations of the Moon have been made with the altazimuth as before in the first and last quarters. The long-focus lens for viewing a church spire distant 355 yards as a fiducial mark was mounted in February, and this mark has been regularly observed throughout the year; and also, when weather permitted, another mark distant 2200 yards from the instrument.

Comet *e*, 1888 (Barnard), was observed on one night; Comet *f*, 1888 (Barnard), on two nights; Comet *e*, 1889 (Davidson), on four nights, and Comet *d*, 1889 (Brooks), on one night, with one or other of the equatoreals. On the occasion of the close conjunction of *Mars* and *Saturn* on September 19, nineteen differential transits and N.P.D.'s of the planets were observed with the S.E. equatoreal, the results of which have been communicated to the Society.

Four disappearances and one reappearance of stars occulted by the Moon have been observed, and ten phenomena of *Jupiter's* satellites. Circumstances were not favourable for such observations in 1889. The occultation of *Jupiter* and his satellites by the Moon on August 7 was observed by five observers.

On May 15, 1889, two trial photographic objectives were received from Sir H. Grubb; one of 6 inches intended as a pilot for the 13-inch object-glasses to be used in charting the heavens; and one of 4 inches as a pilot for the 28-inch refractor which is being constructed for this observatory. Ten photographs were taken with the first lens, and the information thus obtained guided Sir H. Grubb in the construction of the 13-inch objectives. Some photographs taken at Dublin with one of these objectives were received in November, and micrometric measurements of stars on them to a distance of 80′ from the centre were found satisfactory. Photographs taken more recently at Dublin with two other object-glasses made by Sir H. Grubb give equally satisfactory images up to a distance of 80′ or 90′ from the centre. Eighteen photographs were taken with the 4-inch pilot lens, to test the practicability of Sir G. Stokes' principle of reversing the crown lens to correct the spherical aberration introduced by the separation of the lenses, in order to convert a visual telescope into a photographic one. The most suitable distance of separation was determined experimentally, and satisfactory results were obtained, the images being very sharp.

On December 9 and following days the Astronomer Royal paid a visit to Sir H. Grubb's works in Dublin, and inspected the instruments in process of construction for Greenwich and the Cape.

In the spectroscopic department the observation of the displacement of lines in stellar spectra for the determination of their motion in the line of sight has been continued during the past year, and 429 measurements have been made of the displacement of the F line in the spectra of 50 stars, and 18 measures of the *b* lines in the spectra of 8 stars, besides 72 measures of lines in the spectra of Sun, Moon, or planets, as a check on the adjustment of the instrument and on the general accuracy of the work. The spectra of Comets Davidson and Brooks (July 6), and of χ *Cygni*, *R Andromedæ*, and *Uranus* were each examined upon one night.

With the photoheliograph, photographs of the Sun have been taken on 190 days, and 410 selected for preservation, including 14 photographs, with a double image of the Sun, taken to determine the position of the wires with reference to a declination circle. The additional photographs received from India and Mauritius leave only six days in the year ending December 4, 1889, on which no photograph is as yet available for measurement.

The photographs for 1889 showed a continued falling off in the spotted area of the Sun, until June 16, when a period of greater activity commenced, which lasted until the beginning of October. This period was also marked by the appearance of several small spots in unusually high latitudes, both circumstances suggesting that the solar minimum was definitely past. The last three months of the year, however, have shown an almost entire absence of considerable spots.

One hundred and eighty-five photographs, taken at Harvard College, Cambridge, U.S., between the dates September 1, 1875, and November 29, 1876, have been received from the Solar Physics Committee. Of these, 95 have been found to fill up gaps in the Greenwich series, and so many of them as show spots or faculæ have been measured and reduced.

In 1885 a comparison was made between the areas of umbræ, whole spots, and faculæ, as measured upon 4-inch photographs by the two observers of each of twelve pairs of observers, in order to ascertain if there were any evidence of systematic personality in the estimation of areas. During the past year a similar investigation has been carried out for the twenty pairs of observers engaged in the measurement of 8-inch photographs. Both for the 4-inch and the 8-inch pictures the corrections to be applied to the measured areas on account of personality have generally been smaller than the probable error of the mean of two measures, and in the case of whole spots they are quite insignificant The details of these comparisons for 8-inch photographs, together with the determination of the probable error in the measurement

of the 4-inch photographs, will appear in the Introduction to the volume for 1888, the corresponding investigations, viz. the determination of the probable error of the measurements of 8-inch photographs, and of the effect of personality in the measurement of areas on 4-inch photographs, having been given in the Introduction to the Greenwich Observations for 1885.

During June and July the three pendulums which were used in the Indian Survey, and which had recently been swung at Kew, were set up in the Record Room under General Walker's supervision, and observations were made to determine their vibration periods at Greenwich.

These pendulum swings divide into two sets: in the first, the pressure of air in the cylinder in which the pendulum was suspended was reduced to 2 inches; in the second, to 27 inches. At the lower pressure the duration of each swing was 12 hours approximately, at the higher pressure 6 hours. About 8 swings were made with each pendulum in each set, the position of the pendulum being reversed during each set, so that each face of the pendulum-bob was towards the observer during half the swings.

The observations were reduced so as to exhibit the number of vibrations, in a mean solar day, of each pendulum swinging in a vacuum through an infinitely small arc, and at a temperature of 62° Fahr., a correction being afterwards applied to reduce to sea-level. The results as compared with those obtained at Kew are as follows :—

Number of Vibrations in Mean Solar day.

Pendulum.	At Greenwich.	At Kew.
4	86165·54	86166·50
6	86065·70	86066·61
11	86117·04	86117·03

Observations were made in June and July for determining the longitude Dunkerque-Greenwich by Commandant Defforges and Mr. Turner. The English reductions are complete to the first approximation, but the French have been somewhat delayed by the influenza epidemic. This longitude will serve as a check on the longitude Paris-Greenwich by completing a triangle with Dunkerque.

The reductions for the longitude Paris-Greenwich, for which numerous observations were made in 1888, have been seriously delayed by a curious discrepancy between the results obtained by English and French instruments, which has hitherto baffled all attempts at elucidation. It is hoped that the independent determination through Dunkerque may throw light on the matter.

In accordance with a request of the French Service Géographique observations were also made in July for simultaneously determining the difference of latitudes of Paris and

Greenwich by the method of the French Survey. The latitude deduced for Greenwich with the assumed places of the stars observed agrees with the adopted latitude within $0''.15$, a quantity less than the probable error.

The comparison between Hansen's and Burckhardt's Tables of the Moon for the years 1847–1861, recently conducted under the auspices of the Royal Astronomical Society, rendered possible the comparison of the Greenwich lunar observations for those years with Hansen's Tables. This latter comparison has now been made under the supervision of the Astronomer Royal, and the results are being printed in the *Monthly Notices* of the Royal Astronomical Society.

During the summer Lieutenants Field and Cust, of the Royal Navy, made a number of observations at this observatory, to determine the relative advantages of the portable transit and of the sextant for nautical surveying.

The electrical connections and underground wires of the observatory, up to the points where they are connected with clocks or instruments, have been placed under the superintendence of the Post Office; and thus time, which was hitherto necessarily devoted to business in connection therewith, has been reclaimed for scientific work.

A clock with heavy pendulum has been rated for several months at the request of the constructor, Mr. R. Inwards.

It may be mentioned that the Astronomer Royal visited Pulkowa on the occasion of the Jubilee celebration (August 19, 1889), and attended the meeting of the Permanent Committee of the Astrophotographic Conference in September.

The volume of Greenwich Observations for 1887, including the Ten Year Catalogue and two other appendices, was passed for press in December, and is now being distributed. The volume for 1888 is well advanced.

The magnetical and meteorological observations have been carried on without any particular change. By means of two additional stoves placed in the magnet basement, in the beginning of the year 1889, it is practicable to regulate its temperature so that the variation between summer and winter is reduced to very small limits, being now, excepting in the extremes of winter cold or of summer heat, not more than $1°$ or $2°$. The diurnal variation of temperature has always been small, so that the temperature correction (annual as well as diurnal) required for the horizontal and vertical force magnets is now very small.

It has been the custom since the year 1882 to give in the annual volume copies of the photographic magnetic curves for days of unusual magnetic motion, as such publication appeared to afford a valuable means for the directors of other observatories to make comparison with their results. A similar system has since been commenced at the Parc St. Maur Observatory in Paris. But as the days selected at the two observatories in different years were not quite the same, it has now been arranged,

in concert with M. Mascart, that the observatories shall act together in this matter, and the list of days for 1889 has already been selected and agreed upon. If other magnetic observatories would in future years join with Greenwich and Paris in concerted action for the publication of the magnetic curves on selected days, much would be done to facilitate the investigation of the phenomena of terrestrial magnetism.

At the end of the Introduction to the last published volume, that for 1887, there will be found accounts of experiments made on days of extreme heat bearing on the question of the effect of radiation from the ground and surrounding objects on thermometers; a question interesting to astronomers as well as to meteorologists, as affecting the determination of astronomical refraction. There is (1) a table of readings of thermometers on the open stand, with the circular protecting radiation board alternately removed and attached; (2) a table of readings of thermometers in a Stevenson Screen, with the door of the screen alternately open and shut; and (3) a table of readings of the new thermograph, with certain protecting radiation boards alternately removed and attached. There is, further, an interesting comparison of results obtained by the old and new thermographs, as well as a comparison of the records, during one year, of the old Campbell form of sunshine instrument and the new Campbell-Stokes form.

The Thomson Electrometer, for indication of atmospheric electricity, which had been for some months out of use, was finally readjusted by Mr. White, of Glasgow, and again brought into use in October 1889.

The reduction of the twenty years' photographic records, published in 1878, dealt with the barometer records from 1854 to 1873, and the thermometer records from 1849 to 1868. Since 1877 corresponding results have appeared in the annual volumes. An appendix to the 1887 volume contains the reduction of the barometer photographs from 1874 to 1876, and of the thermometer photographs from 1869 to 1876, completing the reduction of the photographic records of the barometer and dry-bulb and wet-bulb thermometers since their commencement respectively in 1854 and 1849.

Royal Observatory, Edinburgh.

During the year 1889, the routine work of reducing the observations of the 55 stations of the Scottish Meteorological Society, as well as the daily meteorological readings and weekly record of the rock thermometers, have been continued as heretofore, under the care of Mr. T. Heath. The same remark applies to the time service by time-ball, time-gun, and electrically controlled clocks. Time signals have also been regularly transmitted to Dundee.

In the course of the year the arrangements for building the new Observatory have slowly progressed. In the spring a committee for the consideration of a site and plans was nominated by H.M. Secretary for Scotland, consisting of Lord Crawford, Professor Tait, Lord McLaren, the late Mr. J. Reid, and Professor Copeland. The committee met on June 17, when Mr. W. W. Robertson, H.M. Surveyor for Scotland, attended by request. On this day a site was eventually selected in Blackford Hill Park, almost exactly two minutes of arc south of the present Observatory. The park being the property of the City of Edinburgh, application was made to the Edinburgh Town Council, who with the greatest liberality unanimously resolved to transfer to the Crown a suitable area of the park, on the sole condition that it was to be used only for the purposes of a National Observatory.

As the site is within 500 yards of the Suburban Railway, it became necessary to test it for stability. This was accordingly done with a 4-inch transit instrument brought from Dun Echt, between September 26 and October 24, the result being that the porphyrite rock of which the hill consists does not transmit any perceptible vibration from the railway, even when the heaviest trains are passing. This important point being decided, the transfer deeds and general plans of the Observatory and dwelling houses were directed to be proceeded with. Building operations will be commenced in the summer.

The instrument used for testing the site remains in position; by using it in the prime vertical Dr. L. Becker found the approximate latitude to be $55^\circ\ 55'\ 57''{\cdot}3$. At present α *Cassiopeiæ* passes the zenith between the two observatories, but, owing to its large precession in declination, it will not long offer the same facilities that Hooke's chosen star, γ *Draconis*, has so long afforded at London and Greenwich.

Professor Copeland took up his residence at Edinburgh on April 11, but Dr. Becker was able to remain at Dun Echt Observatory until September 25, which thus for a short time became a field station of the Edinburgh Royal Observatory. The interesting nature of the work thus rendered possible will be seen from the following summary. In the earlier months of 1889 Dr. Becker continued the observations of nebulæ, mentioned in former reports, with the transit circle. During 14 nights 114 places of nebulæ were secured. Unfortunately, the weather was very unfavourable at the time when the hours of R.A. 10^h to 14^h, so rich in nebulæ, were accessible. The spectroscopic observations of the low Sun on the Barmekin Hill were resumed in May. The brighter part of the spectrum from $\lambda=602$ to 486 having been finished in the two previous years the survey could now only be extended on the clearest days. However, from May 8 to September 9, 2,610 measures of lines in the red end of the spectrum were made during fifteen settings and six risings of the Sun. The skies

were by no means so favourable for this class of observation as in the other two years, the horizon having been much obscured by haze in the month of June and by clouds in July. The whole of these observations will be ready for publication in a few weeks. Dr. Becker also made a careful study of 17 *Cygni* and *β Lyræ* with the smaller Grubb spectroscope attached to the 15-inch equatoreal. On eleven nights in June and July 457 measures of 70 bright lines in the spectrum of 17 *Cygni* were compared with the spectra of sodium, lithium and magnesium. Twenty-eight lines in the spectra of lead and zinc served as standards for the bright lines of *β Lyræ*, of which no less than 237 were laid down by 560 observations. D_3 is not amongst them. These measures have been reduced by the aid of a table computed by Ketteler's formula of dispersion. On October 28, the F line was seen exceedingly bright in *R Andromedæ* and in *R Cygni*, together with many other bright lines of less intensity. A prominent group of these lines occurs in the light of both stars near $\lambda=517$, and there is a very bright one at 494·6. Bright lines were also suspected in several other stellar spectra, but the necessity of concentrating all work at Edinburgh put a stop to the investigations before decisive results could be obtained. Examined on twelve nights from August 18 to September 20 with a Fraunhofer-Secchi prism on the 6-inch Simms equatoreal, *γ Cassiopeiæ* showed C extremely bright, while the other hydrogen lines were seen with difficulty.

A place of comet Barnard 1888 *f* was obtained with the 15-inch equatoreal on January 26, and one of Davidson's comet on August 15. The latter observation was used in computing the orbit published in Dun Echt Circular No. 176. During the year twelve circulars were distributed. They deal almost altogether with comets. A concluding circular, No. 179, was published January 29, 1890. A second series has been commenced at Edinburgh, of which three were issued before the close of the year.

The printing of the text of the library catalogue is now finished.

In his spare time Dr. L. Becker has computed the definitive orbit of comet 1867 I, for which he has observed all the comparison stars at Dun Echt. The period comes out as 40 ± 4 years. By altering the period it becomes evident that it must lie between 30^y and 50^y, and most probably within the narrower limits of 35 and 45 years.

Since the beginning of the winter session Professor Copeland has lectured on Spherical and Practical Astronomy in the University of Edinburgh.

Royal Observatory, Cape of Good Hope.

Observations with the transit circle have been continued regularly throughout the year. The chief objects of observation have been the Sun, *Mercury* and *Venus*, stars in the list of the Cape ten year catalogue for 1890, comet comparison stars, stars occulted by the Moon, stars employed in the latitude determinations of the geodetic survey of South Africa, and stars employed in zones for determining the scale value of the heliometer. In addition the minor planets *Victoria* and *Sappho* and the selected comparison stars were observed during the period June 2 to November 22.

The work accomplished with the transit circle in 1889 has been as follows:—

Number of determinations of collimation	53
,, ,, level	332
,, ,, nadir	330
,, ,, flexure	53
,, ,, meridian mark	74
Number of complete observations of the Sun (both limbs in both elements)	98
Number of complete observations of *Mercury*	49
,, ,, ,, *Venus*	74
,, ,, ,, *Victoria*	49
,, ,, ,, *Sappho*	28

	Direct.	Reflex.
Transits	4284	68
Observations of N.P.D.	3604	68

Of the 42 *Victoria* comparison stars 564 meridian observations were obtained, and of the 38 *Sappho* comparison stars 465 observations.

From the want of an available assistant (no computer being available for any kind of observing), it was necessary to discontinue the use of the great theodolite during the year.

With the zenith telescope 863 pairs of stars have been observed by Talcott's (Horrebow's) method, partly in connection with Kapteyn's method of latitude determination, partly for control on the law of flexure of the transit circle, and for the connection of the northern and southern systems of declination.

The following occultations of stars by the Moon have been observed:—

Disappearances at the dark limb	18
Reappearances at the dark limb	8

Davidson's Comet was observed on eight nights; the results have been communicated to the *Astronomische Nachrichten.*

The heliometer has been kept in constant use during the year. The series of observations for stellar parallax, mentioned in last report, has been nearly completed. The minor planets *Victoria* and *Sappho* have been observed in conjunction with the observatories of Yale, Leipzig, Göttingen, and Bamberg, according to a carefully prepared programme. A heliometric triangulation of the comparison stars, necessary for the satisfactory reduction of the *Iris* observations, has been completed. The work of triangulating the comparison stars observed with *Victoria* has been begun. The solar eclipse of June 27 was observed with the heliometer, in response to a request from Professor Simon Newcomb, under very unfavourable circumstances of definition; but, as 144 pointings each of position angle and distance of the cusps were obtained, the result should be an accurate one. A preliminary discussion shows that the corrections to the *Nautical Almanac* place of the Moon, referred to the Sun, are very small.

In order to determine whether the radius of the slides is identical with the focal length of the heliometer-object-glass (in other words, to ascertain whether in converting observed distances into arc it is necessary to introduce a term depending on the square of the distance), two zones (distortion zones) were selected, each consisting of four stars, arranged nearly on a great circle, the distance of the extreme stars of each zone being about two degrees. One of these zones was observed by Dr. Gill, the other by Mr. Finlay. All the combinations of these distances in each zone were frequently observed, the observations on each night beginning and ending with observations of the extreme stars. The position angles of all the combinations were also observed, to permit the accurate projection of each distance on the great circle joining the extreme stars. The rigid reduction of these observations cannot be made till after completion of the investigation of the division errors of the scales.

Thus during a great part of the year the heliometer was in use nearly every night and every morning, and Dr. Gill found that he could not expose his eyes during this period to the additional strain of making observations for division error of the scales by day. Hence it became necessary to suspend the observations for division error in the end of February, and they were only resumed in November.

At the present rate of progress the whole of this laborious and tedious operation will be finished in February. When this is completed the error of each of the 360 working divisions will be known with a probable error considerably less than $\pm 0''.01$, for there is hardly a single instance in which the two entirely independent determinations of the error of the same division differ by more than $0''.03$.

The actual number of observations made with the heliometer during the year is as follows:—

	Pointings.
Observations for stellar parallax	1408
„ of distortion zones	616
„ scale value zones	64
Triangulations of *Iris* comparison stars	704
„ *Victoria* „	352
Parallax observations of *Victoria*, evening observations .	1858
„ „ „ morning observations	1580
Observations of standard stars in *Victoria* observations .	356
Parallax observations of *Sappho*, evening observations .	55
„ „ „ morning observations .	432
Total	7926

These figures do not include the scale-value zones and Sun diameters measured by Professor Auwers.

During the months of June, July, and August the observatory was honoured by a visit from Professor Auwers, of Berlin.

The favourable opportunity for determining the solar parallax offered by the opposition of *Victoria* and the knowledge that a single observer could not carry out, in the completest manner, the intended programme of observation, induced Professor Auwers, at the earnest request of H.M. Astronomer, to visit the Cape and co-operate in the work. Throughout the opposition of *Victoria* Professor Auwers took alternate watches of observation with Dr. Gill, and it is quite certain that during the whole period (from June 10 to August 26 inclusive) no single suitable opportunity for observation was lost.

When the favourable circumstances of parallax factor are considered, and it is further borne in mind that each of these 3438 pointings probably exceeds in accuracy one of the best meridian observations (with smaller liability to systematic error), and since an almost identical number of similar observations was obtained in the northern hemisphere, it becomes possible to form an estimate of the high value of the service which Dr. Auwers has thus rendered to science.

A large number of photographs, both of *Victoria* and *Sappho*, were obtained with the Nasmyth telescope by Mr. Sawerthal. It was found best to direct the guiding telescope upon the planet, so that upon the plate the image of the planet appears as a sharp round disc, and the images of all the stars are slightly elongated in the direction of the planet's motion. These conditions appear to be the most favourable for determining the position of the planet with least liability to systematic error. Up to the present time no information of corresponding photographic observations in the northern hemisphere has been received.

It happened that, during the period of the *Victoria* and *Sappho* observations, Mr. Finlay (the only observer who had experience in the use of the heliometer) was closely occupied, first with determinations of his personal equation relative to that of Commander Pullen, R.N., and afterwards in carrying out a chain of longitude operations on the west coast of Africa, which the completion of the submarine cable to the Cape had rendered possible. Commander Pullen had volunteered for this service upon quitting (on promotion) the command of H.M. Surveying Ship "Stork," and Mr. Finlay, from his previous experience in like work on the east coast of Africa, was selected as the co-operating observer at the Cape. Commander Pullen remained at the observatory from June 10 till July 31, to acquire familiarity with the use of the altazimuth, and to ascertain his personal equation relative to that of Mr. Finlay, both in time determinations and the observation of mirror signals. It is undesirable to connect a cable with land lines, and the other work of the staff did not, at the time, permit the employment of a second Cape observer. Accordingly a sidereal clock, of excellent quality, was set up in the cable office, Cape Town, and this was compared with the observatory transit clock by the intervention of a mean time chronometer carried by Mr. Finlay (two miles by railway and about half a mile on foot) and compared with both clocks before and after exchange of signals. On account of pressure of other work on the cable four or five hours had sometimes to elapse between the two comparisons; and yet, notwithstanding the possible disturbance of the chronometer rate by transit, there is no single instance in which a discordance between the first and second comparison amounting to one-tenth of a second can be traced, so that no practical gain in accuracy would have resulted by the employment of an additional observer and the comparison of the Cape Town and observatory clocks by telegraphic signals. Although signals were exchanged and time observations made at the Cape nearly every night, only a small proportion of these exchanges could be utilised for longitude purposes on account of the cloudy weather prevalent on the west coast, so that the operations became very trying and laborious in proportion to the number of results obtained. The following stations were successively occupied by Commander Pullen:—

	Dates of Occupation.	No. of nights on which determinations of Longitude were secured.
Port Nallath . . .	Aug. 5 to Aug. 16	5
Massamedes . . .	Aug. 25 to Sept. 10	4
Benguela	Sept. 12 to Sept. 20	4
St. Paul de Loanda . .	Sept. 23 to Oct. 10	3*
St. Thomé . . .	Oct. 12 to Oct. 16	3

* Besides three incomplete determinations of which the details are not yet received.

From St. Thomé Commander Pullen made an expedition to Brass and Opobo, in connection with preparations for a boundary survey which he had orders to undertake at a later date. He reached Bonny on October 27 and was seized with malarial fever the same day. On October 29 he so far recovered as to make observations the same evening and exchange longitude signals with the Cape. These formed the last work of his life; a relapse followed and he died at his post on November 3.

That Commander Pullen had thoroughly mastered the use of the altazimuth, and that this longitude series will prove to be a very accurate and valuable one, must be evident from the following separate results of the longitude of Loanda for the nights when complete observations were obtained at both ends :—

	Loanda, W. of Cape Observatory.
	h m s
1889, Sept. 24	0 20 59·92
25	59·87
26	59·86

The full details of observations at other points have not yet reached the Cape.

The field work of the geodetic survey has been resumed. A number of latitude stations near Port Elizabeth have been occupied, and the abnormal deviations of the plumb-line there have been investigated. Deviations amounting to nearly $\pm 10''$ have been observed.

Major Morris, R.E., is now engaged in the re-measurement of a longitude chain of Bailey's triangles, connecting the southern triangles of Maclear's work with the new system of geodetic triangles at Port Elizabeth.

Mr. Vos, one of the Transvaal Government surveyors, has been studying the use of geodetic instruments at the observatory for the past six months, and leaves in a few weeks to extend the meridian chain of triangles measured in Natal northwards to the Limpopo.

The temptations offered by highly paid employment in connection with gold mining undertakings and speculations in the Transvaal, as well as by the new fields of enterprise in British Zambesia, have robbed the observatory of all its old staff of computers, so that none of the present computers have been able to aid as observers, and from lack of suitable computers the reductions of the observations are daily falling further into arrear. A full report on the subject has been submitted to the Lords Commissioners of the Admiralty and a remedy suggested.

The observatory for the reception of the new photographic telescope (with an admirable dome by Sir Howard Grubb) is completed, and it is promised that the telescope itself will be sent off from Dublin about the end of January.

The meteorological observations made in the year 1888 at

the observatory, together with those taken in different parts of the colony, have been printed in the report of the Cape Meteorological Commission.

H.M. Astronomer desires to convey an expression of his deep obligation to the directors of the many observatories who have so generously and spontaneously co-operated in the observations of *Victoria* and *Sappho* and their comparison stars.

Professor Auwers has undertaken the discussion of the results of the meridian observations, and those astronomers who have not yet communicated such observations are requested kindly to send them direct to him.

In case the reductions of any of the series of observations are not completed by the time this report is published, it is desirable that Professor Auwers be at once informed of the existence of the observations, and of the probable time when the results will reach him, in order that all existing data may be included in the final discussion.

In the case of *Victoria* especially it is found that for the most complete discussion of the whole series of observations it will be necessary to determine the relative places of the comparison stars with such precision that their errors may be regarded as insignificant, or rather as affected by very small and known probable errors. This necessity arises in great part from the fact that short periods of cloudy weather have intervened at the Cape when the skies were clear in the northern hemisphere, and *vice versâ*; so that a number of observations made in one hemisphere are preceded and followed by fine observations in the opposite hemisphere, all of the three series being referred to different stars. Such observations will consequently be lost unless the relative places of these stars are determined with very high precision. It also appears from the various series of meridian observations which have been received up to the present time that the discordances of the places of the different stars in right ascension (apart from a common correction) are so considerable that it will be necessary, in order to secure all desirable accuracy, to supplement the results of the meridian observations with a heliometric triangulation. A detailed plan for this work has been prepared, and Dr. Schur has undertaken to carry it out at Göttingen during the current year. The same will be done (if possible in duplicate) at the Cape, and Dr. Elkin also hopes to be able to include it in the programme of his year's work at Yale. If these intentions and hopes are realised the relative positions of all the stars will certainly be known within $0''.1$, and in the case of the more important stars (those which have been most frequently compared with the planet, and whose more frequent observation is provided for in the scheme of triangulation) with a still higher accuracy.

Armagh Observatory.

The refractor has been chiefly used for observations of nebulæ, but other observations have been made as opportunity offered, among which may be mentioned some physical observations of *Saturn* in the spring, and micrometric measures of the relative positions of *Mars* and *Saturn* at their conjunction on September 19.

The transit instrument by Jones, with which the Right Ascensions of the first Armagh Catalogue were made, has been thoroughly cleaned and the roof shutters repaired. It will in future be used for the time determinations. At the request of the Kew Committee the telescope of the old Kew Mural Quadrant (which had been presented to Armagh Observatory in 1841 with most of the Kew instruments) has been returned to Kew, in order that it might again be attached to the quadrant which is now preserved in the Science Collection at South Kensington.*

Meteorological observations at 9 A.M. and 9 P.M. have been taken and tabulated as usual, and the anemograph and self-recording rain-gauge kept going, and the hourly results tabulated for the Meteorological Office.

Cambridge Observatory.

The original design of obtaining at least three observations of each zone star with the transit circle is now nearly completed; so that the number of meridian observations of the zone stars is of course considerably less than in former years.

We have obtained, during the year, 441 observations of zone stars, 593 of clock stars, 109 of *Polaris*, 13 of *Victoria*, and 180 of stars selected for comparison therewith, 16 of *Sappho*, and 183 of comparison stars; making a total of 1,535 meridian observations.

The collimation, level, and nadir point have each been observed 172 times.

Reckoning from the commencement of our zone work to the end of 1889, there have been taken 51,087 observations of zone stars, and 10,493 of clock stars, in addition to observations of small planets and comets, and stars suitable for comparison with them.

The reduction of such a mass of observations has been found to be no light task for our small staff: yet the progress is satisfactory. The apparent right ascensions and north polar distances are computed up to the middle of September, 1889. The mean right ascensions and north polar distances for the beginning of each year of observation are computed up to the

* This must be the mural arc by Sisson, made in 1770, mentioned by Montucla, *Hist. des Math.* iv. p. 377.

end of 1888. The reduction to epoch is completed in right ascension to the end of 1883, and in north polar distance to the end of 1884.

The zone stars are collected into a ledger as far as 15 hours right ascension up to the end of 1878, and this part of the work is now being pushed forward as rapidly as is practicable, preparatory to the formation of the final catalogue.

Vol. XXII., containing the observations for the years 1866–1870, is printed and will shortly be ready for distribution. Good progress has been made in the preparation for the press of the succeeding volume.

The weather has been unfavourable for observations of Comet "Brooks." We have only been able to see it on two nights, in which we obtained, with the Northumberland equatoreal, sixteen comparisons with suitable stars, and the compared stars have been observed with the transit circle.

Several applications have been made to us during the year for the places of stars included in our zone, which had been compared with comets. Except in a very few cases we have been able to supply the required information.

Dunsink Observatory.

At the date of last report the meridian observations of *Iris* and comparison stars had just been completed, but the reductions were not at that time finished. The results appeared, however, shortly afterwards in the March number of the *Monthly Notices*.

After this the working list of stars with large proper motion which has been referred to in former reports was again brought into requisition for a short time, but very little progress was made with these stars in consequence of the fact that masons were at work in the meridian room preparing a dark-room for the photographic work in connection with the 15-inch reflecting telescope, presented to the observatory by Mr. Isaac Roberts. At the end of April we received Dr. Gill's programme for observations of *Victoria* and comparison stars, and prepared to commence the work at once, but the first observations were not obtained till June 10. In this piece of work we have been very unfortunate, owing partly to the unfavourable weather and partly to several interruptions which occurred during the summer. It was discontinued at the end of August on the receipt of Dr. Gill's programme for similar observations on *Sappho* and comparison stars, which we immediately began to observe. We were able to obtain only 52 observations of 23 of the *Victoria* comparison stars and four of *Victoria*.

In the *Sappho* work, which has occupied the meridian circle since September last, we have a more creditable record, having obtained 229 observations in right ascension and declination of the comparison stars, and eight of the planet itself. With one

exception, we have observed all the stars more than once, and 24 out of the 37 have been observed as often or oftener than Dr. Gill proposed.

A great deal of time has been necessarily spent in overseeing the workmen engaged in altering the dome of the observatory, which has been hitherto occupied by the 5-inch equatoreal, in order to prepare it for the reception of the 15-inch reflector, and consequently the reduction of the meridian observations is in a somewhat backward condition, but it is hoped that the results will be ready for publication by March next.

The "South" equatoreal has been used as in previous years in searching for stars with a large parallax.

On the morning of September 20 the near approach of *Mars* and *Saturn* was observed under rather unfavourable circumstances. A few micrometric measures of the distance between the planets were obtained.

The results of the observations made in 1887 and 1888 for the purpose of determining the latitude of this observatory have been published as a paper by Mr. Rambaut in March last as the Fourth Part of Vol. IV. of the *Scientific Transactions of the Royal Dublin Society*.

Glasgow Observatory.

The operations of the Glasgow Observatory during the past year have mainly consisted in the re-observation of a select list of stars, the places of which, as given in the Glasgow Star Catalogue, cannot be satisfactorily reconciled with the corresponding places contained in Weisse's Bessel Catalogue. This work, which has been prosecuted during the last few years, is now drawing to a close, and it is expected that the results will be published before the lapse of another year.

Much of the computing force of the observatory has been devoted, as in former years, to the reduction of the meteorological observations made at the observatory with self-recording instruments during the period extending from 1868 to 1887. This work may be said to be now finished, and more time will in future be available for the legitimate work of the observatory.

Kew Observatory, Richmond.

The ordinary routine of meteorological and magnetical observations has been carried out during the year, and as usual large numbers of various scientific instruments have undergone examination.

Sketches of sun-spots have been made on 173 days, and the groups numbered after Schwabe's method.

Solar and sidereal transits have been occasionally observed as a check on the times signalled through the Post Office from Greenwich.

Observations have been made with a pair of Violle's actinometers.. These consist of two delicate mercurial thermometers, encased, the one in a well-blackened hollow metal sphere, the other in the centre of a similar sphere thickly gilded and having a highly polished surface. They are suitably mounted and taken out on sunny days, placed side by side in the open air, and then alternately exposed to the solar rays, and shielded from their action, the behaviour of the thermometers being noted.

The collection of Solar negatives from 1858 to 1872 taken at Cranford and at Kew, as well as a large number of undistributed copies of the papers on Solar Physics, by Messrs. De la Rue, Stewart, and Loewy, have been handed over to the Solar Physics Committee, with the view of their being utilised.

It was found that a much more suitable site was offered by the roof of the new building for the working of the cloud cameras; so the pedestal of the Photo-nephograph was removed from the position it formerly occupied and set up on gratings placed thereon, the necessary alterations being effected in the electrical attachments. As, however, the question of the most convenient way of utilising the cloud pictures is still under consideration by the Meteorological Council, no photographs have been taken during the past year.

The Department of Science and Art having accepted the old mural quadrant for exhibition in the science collection at South Kensington, application was made to the Governors of the Armagh Observatory for the telescope and object-glass belonging to the instrument, which had been found by Dr. Dreyer in the Armagh collection of astronomical apparatus. The Committee's request having been acceded to, the missing parts were duly received at Kew and forwarded to the Museum Galleries at South Kensington.

Liverpool Observatory, Bidston, Birkenhead.

Careful attention has been given to observations of stars with the transit-instrument, for the determination of clock errors. The Greenwich mean time has been communicated to the Port by the firing at 1^h P.M. daily, Sundays excepted, of the time-gun on the pier-head of the Morpeth dock. A large number of marine chronometers have been systematically rated in three definite and equidistant temperatures in order to ascertain their thermal errors. For some time after the re-erection of this observatory at Bidston it was the practice in summer, during the week in which the chronometers were exposed to the temperature of 55° Fahr., to place them in a cellar in the basement of the building. This was subsequently discontinued and, as no

artificial means are provided for lowering the temperature in the cases in the chronometer-room, it was decided to adopt a test ranging from 65° to 85° Fahr. during the summer months. The records showed that some chronometers had a different rate in the temperature of 55° Fahr. in the cellar, from that which they had when exposed to the same temperature in the chronometer-room. This was probably due to a difference in the hygrometric condition of the air, although the cellar appeared to be perfectly dry.

We now have a continuous record for the past twelve years of the performance, both at the observatory and also on ship-board, of the chronometers belonging to the Pacific Steam Navigation Company. It appears that when temperature corrections are applied, the rates at sea and on shore are generally nearly the same. In some instances, however, there is a systematic difference. Some chronometers gain, others lose, when at sea, on the shore rate. There is reason to suppose that such changes of rate are sometimes caused by a difference in the humidity. In steam-ships, however, when a marked constant difference has shown itself between the sea and shore rates, proper allowance having been made for thermal error, we have almost invariably found that the chronometers were exposed to an unusual amount of vibration from the machinery.

The meteorological work has been carried on as in previous years. No interruption has occurred during the past year in the records of the self-registering instruments. A report recently submitted to the Marine Committee of the Mersey Docks and Harbour Board, and now in the hands of the printer, gives some tables of results of meteorological elements deduced from observations made at this observatory during the past twenty-two years.

Radcliffe Observatory, Oxford.

During the year 1889 the attention of the observers has been chiefly directed to securing positions with the Transit Circle of all the stars down to the 7-8 magnitude which are visible between 115° N.P.D. and the Equator; but in those parts of the sky where no stars of the required magnitude are visible, stars fainter than the 7–8 magnitude have been observed, to secure the necessary zero-points for differential observations. The resulting catalogue should, with the Cape Catalogue for 1880, afford well distributed zero-points from the South Pole to the Equator.

The observing work is drawing to a close, and some advance has been made in the preparations for a General Catalogue.

The Transit Circle has also been regularly employed in observations of the Sun and Moon; of the minor planets *Victoria* and *Sappho* with comparison stars selected for observations of dis-

tances with the Heliometer. The number of transits observed during the year 1889 has been 3016, and of N.P.D. observations 2228. The Moon has been observed 62 times; the Sun 64 times; the planet *Victoria* has been observed 14 times, and 35 of the selected comparison stars have been observed three times, 2 four times, and 1 twice; the planet *Sappho* has been observed eight times, whilst of the selected comparison stars 4 have been observed three times, 8 twice, and 20 only once. The lunar crater "Mœsting A," at the request of Herr Franz, of Königsberg Observatory, has been observed eight times on the meridian.

The prevalence of cloudy weather during the months of January, April, and December seriously interfered with the observing, and rendered it necessary to introduce special morning watches to clear off certain parts of the catalogue.

The Barclay Equatoreal has been employed in measurements of the double stars ϵ^1 *Lyræ*, ϵ^2 *Lyræ*, Σ 24, 7 *Tauri*, and σ *Orionis*; in observations of Comet Barnard (1888, September 2), Comet Barnard (1888, October 30), and Comet Davidson; in a search for Faye's Comet on three nights, which was, however, unsuccessful from the faintness of the comet; in mapping stars in the neighbourhood of Tycho Brahe's Variable, and of the great nebula in *Andromeda*; in observing the occultation of *Jupiter* by the Moon on August 7, and the conjunction of *Saturn* and *Mars* on September 19; in observations of positions of the minor planet *Victoria*, the crater "Mösting A," a red star (*Lalande* 16320), and of a star occulted by the nucleus of Barnard's Comet on 1888, November 13; in an eclipse of *Jupiter's* III. satellite on August 15; and in determinations of the diameter of a new ring micrometer.

With the Heliometer attempts were made on several nights to measure the position of *Victoria*, but the faintness of the planet, its comparatively small altitude, and broken weather prevented satisfactory work.

The 7-inch and smaller Equatoreals have been used for observation of the occultation of *Jupiter*, and for examination of the lunar crater mentioned above, for subsequent identification in the field of the Transit Circle. The electric light has been successfully employed throughout the year in the illumination of the circle, field of view, clock, &c. of the Transit Circle; the scale of the Heliometer; and the wires, &c. in the field of the Barclay Equatoreal.

A discussion of the solar observations made during the years 1884–1885 has shown that the following corrections appear to be required:—

	1884.	1885.
Mean correction to adopted R.A. of clock stars	$+0^s.049$	$+0^s.039$
Mean correction to N.P.D. observations ...	$+0''.260$	$+0''.166$
Correction to adopted tabular obliquity ...	$-0''.256$	$-0''.157$

The mean excess of the longitudes of the Moon from Hansen's tables over the corresponding longitudes deduced from observations, when the tabular quantities are taken out for the mean solar time found from observation, as at present, amounts to $+17''.4$ for the year 1889; the mean annual excess of Hansen's longitudes of the Moon over those derived from observations, whilst showing periodic fluctuations of $+1''.1$ to $-2''.9$ for the years preceding 1864, has since that period shown a progressive annual increase of more than $0''.7$ superimposed upon the periodic change which previously existed.

The work of the observatory has been, during the past year, interrupted by the serious ill-health of two of the assistants, and also of Mr. Luff, who, after holding for nearly fifty years the office of computer, has been compelled by ill-health to sever a connection which has been honourable to himself and useful to the Observatory. But, notwithstanding these interruptions, the volume of observations for the year 1885 has been distributed; the copy for press for 1886 is far advanced; the entry into the ledgers for 1887 and 1888 is completed; and the R.A. and N.P.D. reductions for 1889 are in a forward state.

The meteorological observations have been carried on with the usual completeness, and include photographic registration of the changes of the barometer and dry-bulb and wet-bulb thermometers; and Dr. Haldane and Mr. Pembrey have made some very interesting experiments at the Observatory on the moisture of the air for a comparison with the results deduced from the dry-bulb and wet-bulb thermometers.

Oxford University Observatory.

During the last twelve months the attention of this observatory has been devoted mainly to the completion of parallax investigations relating to stars of the second magnitude through the application of photography. The results have been recently published at the expense of the University, and are contained in the third fasciculus of the observations made in this institution. They comprise thirty independent determinations of the parallax of eight stars, each referred, with one exception, to four stars of comparison. Since the publication of this fasciculus the parallaxes of three additional stars have been obtained, and in due course will be communicated to the Society. It is hoped also that by January next all stars of the second magnitude, conveniently situated at Oxford, and amounting to some thirty, will have been successfully submitted to the same process. The probable errors of these parallaxes have so far been nearly uniform and amount to about $0''.03$.

The investigations thus described by no means represent the whole occupation of the observatory since the last report. Much

time has been expended on the superintendence of the practical astronomical work carried on by university students, and also on the preparation of illustrated lectures to university extension classes and to other public associations. Much time and attention have also been devoted to the adjustment and examination of several photographic object-glasses, sent for approval in connection with the projected international chart of the heavens. Although none has been yet received wholly satisfactory for the purposes intended, there is now ground for expecting final success in an undertaking which seems to be extremely difficult. Notwithstanding these serious drawbacks, it is confidently hoped that the parallactic investigations already referred to will leave their mark on the history of modern astronomy. Finally, it may be permitted here to record that the University of Oxford has conferred the honorary degree of Master of Arts on the chief assistant, Mr. Plummer, in recognition of his services to the University Observatory.

Temple Observatory, Rugby.

There has been no change in the line of work from that pursued in former years.

Mr. Seabroke has continued his measurements of the motion of stars in the line of sight, the results of which have been lately brought before the Society.

Mr Highton has been measuring double stars as usual, and it is hoped that the measurements made during the last few years will be presented to the Society in a very short time.

Stonyhurst Observatory.

In addition to the ordinary meteorological and magnetical work, which occupies a great portion of the time of the observatory staff, observations of clock stars, of the phenomena of *Jupiter's* satellites, and of occultations of stars by the Moon have been made, as in previous years.

A considerable amount of time was given to experimenting in preparation for the total eclipse of the Sun in December last, both with a 6-inch object-glass by Hilger, and with the 4-inch photographic lens lent by Captain Abney.

Drawings of the Sun showing spots and faculæ on the usual scale were made on 216 days. The Sun was examined, and notes made without drawings on three other days. The examination of the faint evanescent spots has been continued as usual. Measures of the chromosphere and prominences in the usual manner were made round the whole solar disc on seventy-seven

days, and round a portion of the disc on two other days. Observations of the inclination or apparent drift of the chromospheric flames and smaller prominences were made on three days, and observations of the spectra of Sun-spots were made on twelve days.

Papers on Sun-spot spectra and on spots lately observed in high solar latitudes have appeared in the *Monthly Notices*, and a paper is being printed in the *Memoirs* on "Photographs and Drawings of the Sun."

The observatory has sustained, as is well known, a severe loss in the death of its director, the Rev. Father Perry. The story of his last days, as told in many of the journals and periodicals, leaves nothing to be added here in commendation of the devoted fidelity with which he completed the task entrusted to him, regardless of pain and unthinking of life. His premature death has robbed the observatory of those thoughts upon the solar chromospheric observations of ten years which were to have been put on record on his return from Salut Island, and has left the burden, without the experience, to his successor.

Mr. Common's Observatory, Ealing.

The 5-foot mirror not being found on trial to be quite satisfactory, owing to the slight ellipticity of the image of a star, probably due to the fact that the disc of glass had been resting in a sloping position for some years, was taken out in the spring and refigured and resilvered; the image now given is very much better; owing to the very bad weather very little work has however been done with it yet.

The 20-inch mirrors mentioned in the last report have been made, and two of them sent out to the Eclipse of December 22. As far as trials made before they were sent enable one to judge, such short-focus mirrors are likely to be very efficient. One is now being erected for regular use in the house lately covering the 6-inch achromatic which has been dismounted.

A new disc for the 5-foot telescope has been ordered and is expected shortly, as well as several discs of large size for plane mirrors. In view of the much better results that may be hoped for from the use of such plane mirrors as siderostats, particularly in eclipse and spectroscopic work in future, the making of plane mirrors of very large size is next to be taken up.

Mr. Crossley's Observatory, Bermerside, Halifax.

Meteorological observations at 9 A.M. and 3 P.M. have been taken daily as usual for the Registrar General's monthly report, and for Mr. Symons. A few observations of the phenomena of the satellites of *Jupiter* and *Saturn*, and a few occultations of stars

by the Moon, have also been made. As for some years past the 3-ft. reflector has taken up much time, many changes in the mounting, &c., have been made with a view to fit it for good photographic work. A good many photographs of the Moon and stars and a few of the *Orion* nebula have been taken during the year.

Wolsingham Observatory (Rev. T. E. Espin's).

During the past year the sweeps for new stars of the third and fourth types have been continued. Observations have been made on forty-four nights, and ninety-three new stars of the third type and five of the fourth type have been detected. Those detected during the first half of the year were published in *Ast. Nach.* No. 2919. Some attention has been bestowed on the spectra of the variable stars, and R *Leonis*, R *Hydræ*, χ *Cygni*, D.M. + 8°, 3780, and R *Cassiopeiæ* were found to have spectra generally similar to that of *Mira Ceti*, while in the spectra of R *Andromedæ* and S *Cassiopeiæ* the F line was found to be of remarkable brilliancy. The latter star, which should have passed its maximum at the end of December, was probably at a maximum in the middle of November. In the case of each of the stars with the line F very brilliant (R *Andromedæ*, S *Cassiopeiæ*, R *Cygni*), the line was seen *after* the maximum, the observations of R *Cygni* before the last maximum not showing the F line certainly bright at all.

The first proof-sheets of the new edition of Birmingham's *Red Star Catalogue* were received early in August, and were finally corrected as far as page 136 by the end of the year. The work has been remodelled, and divided into two sections: (1) A catalogue of the places, and of observations of 766 red stars; (2) Spectroscopic observations of the stars in the catalogue; in addition there will be a catalogue of ruddy stars, and of stars with spectra of bright lines.

A fine sidereal clock has been presented to the observatory, and a large spectroscope, on the same principle as those in use last year, has been obtained, but a still larger one must be provided.

Dr. Huggins' Observatory.

A preliminary measurement of the photographs of the Great Nebula in *Orion*, taken during 1888 and the early part of 1889, has been made since the Report of last year, and the results have been given in a paper presented to the Royal Society (*Proc. R. S.* vol. xlvi., p. 40). These photographs enlarge greatly our knowledge of the ultra-violet region of the spectrum of this nebula, as they show 29 new lines. In 1882, I discovered a strong

bright line about λ 3724; this line has been seen in some of the photographs, and four new lines near it. Besides these, several new groups of lines have been found between λ 3825 and λ 4116.

In one of the photographs taken in 1888 the continuous spectra due to two of the four bright stars of the Trapezium are seen upon the plate. Across these continuous spectra at least four groups of bright lines can be detected, of which the greater number can be traced into the nebula for some distance from the continuous spectra, but in the case of the group λ 4116 to λ 4167, the lines extend but for a very little distance into the adjoining nebula. These groups of bright lines appear to show that these stars of the Trapezium are not merely optically connected with the nebula, but are physically bound up with it. In one of the photographs the strong line about λ 3724 is absent, but some new faint lines can be detected, and it seems highly probable that the spectra of different parts of the nebula are not the same in the ultra-violet region. Further information on this point is expected from new photographs which are now being taken.

In 1874 (*Proc. R. S.* vol. xxii., p. 253) I obtained by direct comparison with a thin line of lead, used as a fiducial line, a determination of the position of the principal bright line in the visible region of the spectra of the *Orion* nebula and six other nebulæ, with an accuracy certainly as great, as stated in the paper, as λ 0000·65. This relative position, translated into wave-lengths, gives for the brightest line λ 5004·6 to λ 5004·8.

The micrometric measures of D'Arrest, of Vogel, and of Copeland, agreed in assigning to this line the wave-length 5004. The wave-length of the termination of the magnesium-flame band is λ 5006·5, showing that it lies on the less refrangible side of the nebular line. Direct comparisons, made last spring under conditions in which the third line is found to coincide with Hβ, showed certainly that the 1874 determination was correct, and that the nebular line is more refrangible than the termination of the Mg flame band by about λ 0001·6 to λ 0001·9.

During the summer of last year the spectroscopes were furnished with new and sensibly perfect object-glasses by Sir H. Grubb. A re-examination with them since, of the visible spectrum of *Orion* confirmed all my earlier observations of the principal line in that it is perfectly defined at the less refrangible side, which is bright and free from flare.

Some unpublished observations on the position of the principal line in the spectrum of the aurora made in 1874, have been worked up (*Proc. R. S.*, vol. xlv., p. 430). These give for this line the wave-length λ 5571 ± 0·5. Vogel's measures in 1872 assign a position of λ 5571·3. These values agree closely with Gyllenskiöld's mean of his own and other observations from 1867 to 1884, namely λ 5570·0 ± 0·88

Observations of the spectrum of *Uranus*, which I made in 1871, showed that it was crossed by several strong lines of

absorption, but the planet's spectrum was too faint to enable me to distinguish the Frauenhofer lines, which were presumably present. Last year, with an exposure of two hours, we obtained a photograph of the spectrum of *Uranus* which extends from a little above F to beyond N in the ultra-violet. This photograph sets the question at rest, as it shows all the stronger lines of the solar spectrum, which were recognised by direct comparison with a pair of sky-spectra, one on each side of the planet's spectrum, which were taken on the same plate. There can be no longer any doubt that the spectrum of *Uranus*, at least from a little above F to beyond N, is due to reflected solar light.

Several photographs of the spectrum of *Saturn* were so taken as to show the spectrum of the ring distinct from that of the ball. The spectra of the ring and of the ball were compared with sky-spectra taken upon the same plate. In these spectra no lines, bright or dark, other than those of the solar spectrum could be detected.

Photographs of *Vega* with long exposures have shown, as was to be expected, that the limit of light in the ultra-violet region which can reach us through the Earth's atmosphere, as shown by photographs of stellar light, is the same as was known to exist for the solar spectrum.

At this observatory the light of *Vega* is abruptly weakened at λ 3000, and sensibly extinguished about λ 2970. Solar spectra taken under similar circumstances show approximately the same limits of absorption and of extinction.

Four photographs, with very long exposures, have been obtained of the spectrum of the great nebula in *Andromeda*, and the same number of the spectrum of the Dumb-bell nebula; but the results, which are new, are reserved for the present. We shall probably wait for further photographs to be taken next autumn before entering upon a discussion of the photographs we have already obtained.

Rousdon Observatory, Devon (Mr. C. E. Peek's).

During the past year 159 nights have been clear, wholly or in part; 23 variable stars are under constant observation. No change has taken place in the staff or instruments.

Mr. Isaac Roberts' Observatory, Maghull.

The photographic work done at this observatory during the past twelve months is not large in quantity, owing to the sky being seldom clear. After careful watching each night, it was found that only four intervals, each of two hours' or longer duration, occurred between February 4 and November 20, 1889.

Since November there have been five intervals suitable for photographic work, and the results obtained will be communicated to the Society.

In consequence of the normally cloudy state of the sky here, an observatory and residence are being erected on Crowborough Hill, in Sussex, whither, in the course of next summer, it is intended to transfer the instruments; and it is expected (in reliance upon the result of extensive inquiries made and reports received) that a better record of stellar photographic work may be shown in future from thence.

The following is a list of the enlarged photographs which have up to this date been presented to the Society, and described in the *Monthly Notices*; and selections of six of them have been presented to about seventy observatories, and to astronomers in several parts of the world:—

	Plates.
1886, August, Stars in *Cygnus*	4
R.A. 19h 45m. Declination +35° 30′	
„ 19 55. „ 37 45	
„ 20 4. „ 35 30	
„ 21 2. „ 38 12	
November, Nebulæ in the *Pleiades*	2
1887, January, „ „	1
Nebula in *Orion*	1
The minor planet *Sappho*	3
June, Cluster M. 13 *Herculis*	2
July, Nebula M. 57 *Lyræ*	2
August, Dumb-bell nebula, M. 27 *Vulpeculæ* ...	1
Stars in *Cygnus*:	
R.A. 19h 45m Declination +35° 30′ ...	1
1888, October, Dumb-bell nebula, M. 27 *Vulpeculæ* ...	1
Nebula in *Andromeda*	1
December, „ „	1
Nebulæ in the *Pleiades*	1
1889, March, Nebula in *Orion*, photographic analysis	7
Nebulæ M. 81 and 82 *Ursæ Majoris* ...	1
April, Spiral nebula, M. 51 *Can. Ven.*	1

The Earl of Rosse's Observatory, Birr Castle.

During the past year a series of sketches of the Milky Way, on which Dr. Boeddicker had been engaged for several years, were completed and combined in a set of four—one of them an index-map on about half the scale of the other three—which are now lying, pending publication, in the rooms of the Society, and have been noticed elsewhere. This work from its commencement has taken very much more time than had been anticipated, and from affording useful occupation only in the intervals amid the proper work with the instruments of the Observatory, came to monopolise in a very great measure the time and energy of the observer.

The complete reduction of the heat-observations during the lunar eclipse of January 28, 1888, has since been resumed, and is expected to be soon complete. Their publication will bring to a close our lunar radiation work with the Thomson reflecting galvanometer and thermo-couple, as it does not seem probable that the work can be further pursued with advantage with our present instrumental means. The subject, however, may be well worth pursuing with improved appliances.

Some desultory photographic work has been carried on at intervals, but it becomes pretty clear that, without considerable modifications, our instruments cannot successfully compete with more modern instruments, though of smaller size, which have been specially designed for this new work, and the wonderful success obtained with the latter leads one to pause and ask, Can the pencil of the draughtsman be any longer profitably employed upon nebulæ as seen through the 6-foot when photography, to say the least, follows so closely on his heels?

The 3-foot equatoreal seems capable of adaptation to photography, but the 6-foot mounting, though most convenient for the purpose for which it was designed, the re-examination of the objects in Herschel's Catalogue with greater "space-penetrating power," can only, we think, be adapted for photographing nebulæ by entirely re-mounting it. This would, obviously, be a task not to be undertaken without the most careful consideration.

The readings for the Meteorological Office have been continued as usual.

Colonel Tomline's Observatory.

The same course of work has been pursued at the Orwell Park Observatory as in previous years. All the comets of the year (with one exception) have been observed upon each occasion when the observation was possible; one observation only being made upon each night, and that one consisting generally of eight separate comparisons of the comet with a single neighbouring star.

While sweeping for Comet *b* 1889 (Barnard, June 23) on July 1 the declination axis of the equatoreal became immovable, and the work was consequently interrupted for some weeks, unluckily at a time when it would otherwise have been actively and advantageously pursued. The telescope was dismounted on August 19, and the axis ground to the bearing by Mr. Simms, since which time the working has been entirely satisfactory.

The following table gives a summary of the observations that have been made :—

Comet.	No. of Observations.	Total number of separate Comparisons.	Limiting dates of Observation.
Barnard (*e* 1888)	12	83	Jan. 1 to July 22
Barnard (*f* 1888)	12	93	Jan. 1 „ Mar. 25
Barnard (*b* 1889)	8	53	Sept. 5 „ Oct. 31
Brooks (*d* 1889)	31	233	Aug. 29 „ Dec. 25
Brooks (companion to *d*)	13	50	Sept. 16 „ Nov. 12
Davidson (*e* 1889)	20	140	Aug. 29 „ Nov. 13
Swift (*f* 1889)	3	23	Dec. 11 „ Dec. 24
Borrelly (*g* 1889)	1	9	Dec. 25
Total observations of Comets	100	684	
Observations of faint or unknown Comparison Stars	21	93	

On August 25, after an illness of eight months, Colonel Tomline died at his residence in London. He had maintained the observatory for rather more than fifteen years, but, recognising that his successor might not be willing to follow in his footsteps, he had already made some preparation for definitely closing the establishment.

The work for the future will therefore be carried on only so far as to complete the series of cometary observations at present begun, or at most such work only will be undertaken as may be completed and reduced within a very limited time. It is uncertain at present whether the means will be found to enable the observer to bring the work, which is still unpublished (*i.e.* nearly the whole of that enumerated above), into a form suitable for publication, but every effort will be made to do so.

Hong Kong Observatory.

The electric time-ball has been dropped as usual at 1 P.M. The second standard clock is expected here in May next, and a chronograph has been ordered subject to the approval of the Astronomer Royal.

Sir W. Thomson's automatic tide-gauge has been marking continuously, and three years' trace is now available. Hourly readings have been finished for the first two years. They are made by two native assistants, whose readings are compared, and, in case of doubt, the trace is inspected.

Meteorological observations and researches, daily weather-reports and storm-warnings, were continued as in previous years. The spectroscopic rain-band was observed every morning, and the strength of the band is found to indicate rain, and particularly great thunder-storms, beforehand. Magnetic observations were made as in previous years. Some eclipses and occultations were observed with the Lee Equatoreal.

The fifth annual volume was published early last year. The printing of the sixth volume is not yet begun. It will probably be published in the course of next year, and will contain the hourly tidal readings in an appendix.

Melbourne Observatory.

The ordinary routine work, astronomical, meteorological and physical, has been carried on during 1889 as usual. The meridian work includes observations of stars selected from the Berlin *Jahrbuch*, as well as of *Sappho* and *Victoria* and comparison stars, according to Dr. Gill's programme.

The great reflector has been dismantled for the greater part of the year for the purpose of refiguring and repolishing the two four-feet mirrors, which had become so tarnished by nearly twenty years' use as to be unfit for delicate observations. This task has been of greater difficulty than was anticipated, but after numerous failures and partial successes one mirror was satisfactorily completed early in December, and it is expected the telescope will shortly be in use again.

In the extra-meridian work of the year, which has nearly all been done with the 8-inch equatoreal, is a preliminary spectroscopic survey of southern stars as a help to a more careful and systematic examination with the large telescope. Some advance sheets of this work have already appeared in the *Monthly Notices*.

Preparations are in progress for carrying out the Melbourne share of the astrophotographic charting of the heavens. A new building for the telescope has been erected close to, but unattached to the south end of the main building, and contains on the ground floor a well-fitted photographic room, store room, &c., above which is the telescope chamber, covered by an 18-feet hemispherical dome of wood sheathed with copper. Everything is ready for the reception of the telescope now being constructed by Sir Howard Grubb, and which it is expected will arrive within a month or two.

The routine work of the Observatory comprises transit-circle observations of fundamental N. A. stars, standard circumpolar stars, and special lists of comparison stars for comets and for other purposes, extra-meridian observations of all comets not in a good position for northern observatories, daily sun photographs, magnetographs of magnetic variations, monthly determinations of absolute magnetic values, and the usual work in local and inter-colonial meteorology, time distribution, rating chronometers, &c.

The annual visitation of the Board of Visitors was held on September 3.

Sydney Observatory.

The year 1889 has been here very unfavourable for astronomical work. Continued cloudy and unfavourable weather rendered observation nearly impossible. An estimate of it may be formed from the fact, that on only one night in the year was definition sufficiently good for measures of close double stars, and on only six nights good enough for stars under 2″ distance. Fifty-six double stars were measured with the large equatoreal, fourteen observations were made of Comet Davidson on five nights, Comet Barnard 1888, September 2, was observed on four nights, the careful examination and delineation of *Jupiter*, which has been regularly carried on since 1876, was continued. Twenty-three coloured drawings of the planet have been made and two sets of micrometer measures of positions and dimensions of the various belts made. Frequent observations of the magnitude of η Argûs have been made. Mr. J. E. Davidson reported to Sydney Observatory on July 21 the discovery on the previous evening of the comet which bears his name. On July 22 the comet was observed here and a cablegram sent to Europe of its discovery. Regular work has been kept up as weather permitted with the Transit Circle.

Number of determinations of Collimation	...	...	304
„ „ „ Level...	...	...	410
„ „ „ Azimuth	...	...	216
„ „ „ Nadir	...	...	304
Number of stars observed in R.A. ...	...	...	2,171
„ „ „ N.P.D.	...	...	812

During the year the determination of longitudes in conjunction with the trigonometrical survey has been continued as in previous years, and to this work fifty-two of the available observing nights have been given: the longitudes of seven inland towns have in this way been determined.

During the year preparations have been made for the astro-

photographic work, and preliminary arrangements have been made with the view of placing this instrument out of the city smoke on an elevation of 620 feet above the sea, in a most favourable position for such work; it is easily accessible by railway and is eleven miles inland from the present observatory. The observatory for this instrument has been made of thin corrugated iron in order to secure rapid assimilation of temperature, and the whole of the mounting and clock-work for the telescope have been made in the colony. The object-glass has been made by Sir Howard Grubb. The Astronomer Royal has kindly consented to test it before it is sent out, and it is expected to arrive in February or March, when the experimental work will be begun.

The polar-axis tube, &c., of this astro-photographic telescope will weigh about two tons; the form is similar to that in use in the Paris Observatory, and unusual weight has been given to the moving parts in order to avoid tremors in the instrument itself.

The illumination of the large equatoreal micrometer and circles by incandescent lamps worked by E.P.S. cells charged by means of a gas engine and dynamo continues to give great satisfaction; a similar method of illumination has been applied to the $7\frac{1}{4}$-inch equatoreal with equally satisfactory results, and cells and a more powerful gas engine have been provided to extend this method to the Transit Circle and to supply electricity for the various chronographs and recording apparatus, &c.

During the year the micrometers for the $11\frac{1}{2}$-inch and $7\frac{1}{4}$-inch equatoreals have been altered, so that now one incandescent lamp turning with the moving parts throws two rays of light on to the wires, giving a perfectly steady and satisfactory illumination, the amount of which is completely under control at the eye end of the telescope.

All the instruments are in good order, the self-recording and general meteorological work have been continued as usual, two weather maps are issued each day, and meteorological observations are received and published from 1,050 stations in this Colony.

One remarkable effect of the weather upon astronomical work cannot be passed over: from May 24 to 29 rain fell to the extent of 20 inches at the observatory, and from 20 to 26 inches over all the district to west of it for 30 miles. When the storm was over the level error of the Transit Circle was found to be 6″ less than it was before. Such a change would be produced if the weight of the rain were sufficient to cause a sinkage in the surface of the ground west of the observatory. The level, I may add, took about six months to recover its normal position. The fact is worth recording without assuming that we have proof that the weight of rain on the ground did cause the change of level. The pier of the Transit Circle rests on a hill of solid sandstone, and all the surrounding circumstances are opposed to the supposition that the change of level was due to an effect in the immediate locality of the instrument.

Mr. Tebbutt's Observatory, Windsor, New South Wales.

In consequence of the large proportion of cloudy nights during the year 1889 the work done at this observatory is rather limited. The instrumental errors of the 3-inch transit have been as steady as in the preceding year, and 833 star-transits, including azimuth stars, have been observed for local time. The extra-meridian work is as follows:—

Thirty-two disappearances of stars at the Moon's dark and two reappearances at the bright limb were observed—namely, twenty-eight with the 8-inch, four with the $4\frac{1}{2}$-inch, and two with the $3\frac{1}{4}$-inch telescopes. Of the thirty-two stars occulted twenty-six have been identified.

Phenomena of *Jupiter's* satellites were observed chiefly with the 8-inch telescope as follows: Transit ingress, I.2; II.2; III.1; IV.1. Transit egress, I.3; II.1; III.2; IV.1. Occultation disappearances, I.1; II.1. Occultation reappearances, I.3. Eclipse disappearances, I.3; III.2. Eclipse reappearances, I.1; II.1; III.1.

Observations were made with the filar micrometer on the 8-inch equatoreal of *Juno* on February 22, March 3, 5, 6, 11, 15, 16, 17, 21, April 1, 2, embracing 119 comparisons and 9 comparison stars; *Hebe* on September 1, 4, 7, 8, 9, embracing 45 comparisons and 7 comparison stars; and of *Flora* on August 10, 12, 13, 14, 19, 20, 21, 23, embracing 81 comparisons and 10 comparison stars.

The following comets were observed with the square bar-micrometer, the $4\frac{1}{2}$-inch equatoreal being employed on August 14, 15, and the 8-inch equatoreal on all the other dates: Comet I. (Barnard 1889), on January 2, 4, 5, 6, June 23, 26, 29, July 1, comprising 70 comparisons and 8 comparison stars; Comet IV. (Davidson 1889), on July 23, 24, 27, 28, 29, 31, August 14, 15, comprising 62 comparisons and 14 comparison stars; and Comet V. (Brooks 1889, July 6) on October 25, 28, comprising 10 comparisons and 3 comparison stars. Brorsen's periodical comet was searched for with the help of Dr. E. Lamp's ephemeris in No. 2933 of the *Astronomische Nachrichten* on December 21, 25, but without success. The well-known binaries *p Eridani* and *γ Coronæ Australis*—the latter at the suggestion of Mr. Gore—have been measured, and the magnitudes of *η Argûs* and *R Carinæ* determined on several occasions.

The usual 9^h A.M. meteorological observations have been made throughout the year with great regularity, and upwards of five months' records of the times and magnitudes of the local tides have been secured by means of a self-registering tide-gauge.

Finally, all the preceding observations have been made, and the greater part of the reductions executed, by the director himself.

Erratum in last Report: For *μ Argûs* read *η Argûs*.

Notes on some Points connected with the Progress of Astronomy during the past Year.

Discovery of Minor Planets.

The following six minor planets were discovered in the year 1889:—

No.	Name.	Date of Discovery, 1889.	Discoverer.	Place of Discovery.
282	Clorinda	Jan. 28	Charlois	Nice
283		Feb. 8	,,	,,
284		May 29	,,	,,
285		Aug. 3	Palisa	Vienna
286		Aug. 3	Charlois	Nice
287	Nephthys	Aug. 25	Peters	Clinton

The Comets of 1889.

At the beginning of the year three comets were visible, viz. the periodical comet of Faye, of which an admirable series of observations was made at the Lick Observatory, extending from August 1888 to the following February, and two others, both discovered by Mr. Barnard. Of these two comets, that detected on 1888 September 2, was observed up till the end of October 1889, and the other, first seen on 1888 October 30, remained under observation till May. The discussion of the observations of the former of these two comets shows that the orbit is hyperbolic, and the long period over which the observations extend makes this conclusion trustworthy. There is, too, some reason to believe that this deviation from the parabola is due to an approach of the comet to the planet *Uranus* in 1882. During the year no less than seven comets have been discovered.

I. On 1889 January 14 Mr. Brooks, of Geneva, N.Y., discovered a faint telescopic comet in Sagittarius, just before sunrise, which, owing to its unfortunate position, and the increase of moonlight, was never seen again.

II. Mr. Barnard added another to his many cometary discoveries by detecting, on March 31, a small faint comet in

Taurus. It was described as 10″ in diameter, and with a tail some 15′ long: but it always remained an inconspicuous object, being at a great distance from both Sun and Earth. The comet was observed throughout April, in May and June it was too near the sun for observation, but towards the end of July (after perihelion passage) it again became visible, and was followed up till November. The observations are fairly represented by a parabola.

III. On June 23 Mr. Barnard discovered another comet. It was an extremely faint nebulosity, about 2′ in diameter, and, growing fainter, was seen but for a few weeks, being lost early in August. The observations show some deviation from parabolic motion, and elliptic elements have been computed by Dr. Berberich, who assigns a period of 128 years to the orbit; but this discussion is not yet definitive. The faintness of the comet easily explains the fact that it has not been observed at any earlier apparition.

IV. A second comet, discovered by Mr. Brooks on July 6, possesses considerable interest. This object when first seen was rather faint, and with a short wide tail, and up to the end of July did not undergo any great change in appearance. On August 1, however, Mr. Barnard telegraphed that the comet had separated itself into several distinct parts, thus exhibiting the same feature of ready disintegration which had characterised the great comet of September 1882. The continued observation of the component parts has on this occasion, however, been more complete, the large telescopes of the Vienna and Lick Observatories having been employed in a careful and continuous study of the structure of the comet. The details of these observations will be found given in the *Ast. Nach.*, Nos. 2919, 2922.

The orbit also is interesting. The small inclination and direct motion suggested a periodic character, which calculation has established: the period, though at present a little doubtful, will not differ much from seven years. The orbit at aphelion approaches very closely to that of *Jupiter*, and in 1886, from March to July, according to Mr. Chandler, the comet's distance from the planet did not exceed one-tenth of the Earth's mean distance from the Sun. It is, therefore, probable that the elliptic character of the orbit was assumed during that time, in which case the resemblance between this orbit and that of Barnard, 1884, II., must be regarded as accidental.

V. A naked-eye comet, first seen by Mr. Davidson, of Queensland, on July 19, who described it as exhibiting a bright nucleus of about the fifth magnitude, with some extension of nebulosity, but no tail. When seen on July 22 at Melbourne, however, a tail of about 30′ long was visible, but the comet had then passed its greatest brilliancy and was rapidly fading. Its motion carried the comet from *Centaur*, where it was first perceived, through *Libra* and *Serpens* to *Hercules*, so that observations in the northern hemisphere were easily possible. It was followed to

the end of November, but the observations are fairly represented by a parabola.

VI. On November 16 Mr. Swift discovered a faint comet in *Pegasus*, but increasing slightly in brilliancy. It presented the ordinary cometary appearance, without tail or pronounced nucleus. The deviations from the parabola were soon sufficiently marked to show ellipticity, and a period of about seven years has been assigned to the orbit. The period is, of course, somewhat uncertain, and at the end of the year the comet is still under observation.

VII. The catalogue of cometary discoveries for the year was completed by M. Borrelly, of Marseilles, who on December 12 saw a faint comet in *Lyra*. This, like the last mentioned, is still being observed, and is increasing in brilliancy, the maximum intensity of light being reached on January 24. There is at present no reason to suspect ellipticity. W. E. P.

The Corona of 1889.

In the year 1889 there were two successfully observed total solar eclipses. The first, on January 1, was visible in California, and the considerable resources of the fixed observatories of the United States were drawn upon unsparingly to make the occasion productive; while at the same time the army of amateurs anxious to assist to the best of their ability was most skilfully organised. A large number of beautiful photographs of the corona were obtained, especially by the parties from the Harvard College Observatory (who used, among many other instruments, a 13-inch telescope), and from the Lick Observatory. Many spectrum-photographs were also taken, in some of which a staining of erythrosin was used to render the plates sensitive in the red and yellow. The amateurs made drawings under the printed and circulated directions of Professor D. P. Todd and others. Special mention should, however, be made of the Amateur Photographic Association, whose members, to the number of twenty, undertook a special research with small instruments, dealing with the progressive differences in result obtained with different exposures.

The eclipse of December 22 was not so well adapted for observation. Available stations were Trinidad, Cayenne and the neighbourhood in French Guiana, and Cape Ledo in South Africa. The Royal Astronomical Society sent observers to Cayenne, and to Cape Ledo, equipped with similar instruments, viz. a pair of 4-inch lenses and of 20-inch short-focus mirrors, with which to photograph the corona; but bad weather at Cape Ledo prevented any advantage resulting from the *double* expedition. A large party from the United States who were stationed at Cape Ledo were also disappointed of results. At

the Salut Isles near Cayenne, totality was observed in a fine interval between storms. Father Perry and his assistant carried out the programme drawn up for them with complete success: but the expedition resulted in the death of Father Perry. He died from dysentery within a few days of the eclipse. Professors Burnham and Schaeberle from the Lick Observatory also obtained coronal photographs at Cayenne, and M. de la Baume Pluvinel from Paris made successful observations. At Trinidad clouds prevented observation.

The photographs of the corona at both eclipses show a remarkable similarity to one another and to those of the 1878 eclipse. It seems to be now well established that the corona of a sun-spot minimum is of a distinctive character; its boundary is very roughly similar to that of a rather flat, empty cotton-bobbin with feathery bunches protruding from wide axial openings. The broad groove for the cotton is not always represented on both sides of the Sun's disc. On January 1, 1889, and December 22, 1889, it is more strongly marked at the eastern limit. The flatness and parallelism of the top and bottom of the bobbin are often surprisingly definite for so flimsy a structure as the corona; but on December 22 there is a marked exception, the south-east boundary of the equatoreal portion being nearly normal to the limb and inclined at about 45° to the direction of the south-west boundary. It is divided from the feathery structure at the poles by a remarkably definite rift, prominent in all the photographs. The limit of the photographed corona is apparently about a diameter from the limb, though eye observation claims a much greater extent for the corona. The 20-inch mirrors taken out by the English expeditions of December 22 were constructed to determine whether this discrepancy was due to want of power in photographic apparatus. The mirrors had an effective aperture of 15 inches and a focal length of only 45 inches, so that they may be taken to fairly represent a great increase in photographic power. But the plates taken with them at Salut show no greater 'extension' than those taken with a 4-inch lens. This result, however, does not appear to be conclusive; the failure of the 15-inch mirror to show more than the 4-inch lens may apparently be due to some accidental and purely instrumental circumstance, for it affects the short exposure photographs, as well as the longer, and is really a failure in instrumental power, and not in the light of the object photographed. It seems probable that in the very damp weather, during which the eclipse took place, a film of dew may, in spite of every precaution to the contrary, have settled on the mirror and decreased its brilliancy. We have, therefore, no conclusive evidence against the future possibility of photographing these faint outer portions of the corona, if they exist.

All hopes of detecting changes in the corona during the two-and-a-half hours which elapsed between the occurrence of totality at Cayenne and at Cape Ledo, by comparison of the two sets of

photographs, were destroyed by the failure at the African station.

Most of the plates used at these eclipses were fitted with standard squares on Captain Abney's principle, allowing of the subsequent determination of photometric intensity. There has not yet been time to obtain definite results.

The photographs of the spectrum taken on January 1 show it to be very simple in character. According to Mr. W. H. Pickering it contains little besides the hydrogen lines; but here also detailed measures will require more time. H. H. T.

Professor Harkness' Researches on the Masses of Mercury, Venus, and the Earth.

"There are in existence not less than fourteen determinations of the mass of *Mercury*, and not less than nineteen determinations of the mass of *Venus*; but the separate values differ largely among themselves, and it is impossible to deduce any trustworthy means from them. A re-discussion of the original data seems the only satisfactory course, and that is the object of the present paper."

From the available materials Professor Harkness deduces four groups of equations for determining ν, ν', and ν''; where these quantities (referring respectively to *Mercury*, *Venus*, and the *Earth*) are connected with the masses of the planets in the usual way—viz., $m = m_0 (1 + \nu)$, m being the true, and m_0 the assumed, value of the mass. The first group of equations depends on the motions of the nodes of *Mercury* and *Venus*, and is deduced from a discussion of the transits of these planets across the Sun, together with meridian observations of *Venus* made at Greenwich, Paris, and Washington during the years 1836 to 1871. The second, third, and fourth groups of equations are taken from the *Annales* of the Paris Observatory, and have been derived: 1. From the secular motions of the perihelion, inclination, and node of *Mars*. 2. From a near approach of *Mars* to ψ^2*Aquarii* on October 1, 1672; the longitude of *Venus* deduced from Horrox's observations of the transit of December 1639; the longitudes of *Venus* obtained from Bradley's meridian observations; the longitudes of *Venus* obtained from meridian observations between the years 1766 and 1830; the latitudes of *Venus* resulting from the observations of the transits of 1761 and 1769; and the latitudes of *Venus* obtained from the Greenwich meridian observations made between the years 1751 and 1830. 3. From observations of the Sun. It will, of course, be understood that in his re-discussion of these materials Professor Harkness uses the modern, and presumably improved, values of the masses of the exterior planets, and other numerical data that enter into the equations. The degree of accordance obtained by Professor Harkness can be most clearly seen by setting down the separate

values of ν, ν', and ν'', deduced from each of the above-mentioned groups of equations. The values of ν are—

$-0\cdot566867 \pm 0\cdot427$
$-0\cdot265744 \pm 1\cdot511$
$-0\cdot619604 \pm 0\cdot09692$
$-0\cdot770229 \pm 0\cdot317.$

The values of ν' are—

$-0\cdot012330 \pm 0\cdot00575$
$-0\cdot055742 \pm 0\cdot03576$
$-0\cdot052249 \pm 0\cdot04755$
$+0\cdot003688 \pm 0\cdot00749.$

The values of ν'' (deduced from the second and third groups only) are—

$+0\cdot148078 \pm 0\cdot03847$
$+0\cdot089161 \pm 0\cdot01301.$

The final values were deduced from the simultaneous solution of all the equations in the various groups, which were first reduced to a uniform standard of weight. The results for the reciprocals of the masses are—

Mercury $= 8704559 \pm 1724742$
Venus $= 404681 \pm 2134$
The Earth $= 332768 \pm 1778.$

The value of the Solar Parallax resulting from this value of the mass of the Earth in conjunction with the best modern values of the length of the seconds-pendulum, the length of the sidereal year, and the size and figure of the Earth, is $8''\cdot795 \pm 0''\cdot016$.

Professor Harkness' paper is published in the *Astronomical Journal*, No. 194. In a subsequent No. of the *Journal*, Professor Harkness points out that the value of the mass of the Earth given above really includes that of the Moon. Making allowance for this, the resulting value of the Solar Parallax is $8''\cdot759$.

Dr. H. Struve's Researches on Saturn's Satellites.

Dr Hermann Struve has published in the current volume of the *Astronomische Nachrichten* (Nos. 2945–46) an important paper entitled "Preliminary Results from the Observations of the Satellites of *Saturn* made with the 30-inch Refractor." In a former volume of the *Nachrichten* the same astronomer discusses a series of comparative observations of the satellites *Iapetus* and *Titan*, and another series of comparative observations of *Titan* and *Rhea*, made with the 15-inch refractor of the Pulkowa Ob-

servatory. Recognising the systematic errors to which micrometric observations are liable when it is attempted to compare a satellite directly with the limb of the planet, the author prefers to measure the relative position of the two satellites rather than the position of each with reference to *Saturn*. In a separate publication entitled "Supplement I. to the Pulkowa Observations," the author gives a more complete discussion of his observations of *Iapetus* and *Titan* and those of *Titan* and *Rhea*, as well as of a shorter series of observations of *Rhea* and *Dione*, all of these observations being comparative, and made according to the plan above mentioned. From the equations of conditions given by these observations, Dr. Struve deduces the corrections of the assumed elements of the satellites' orbits by the method of least squares. He also finds the value of the mass of *Saturn* $= \frac{1}{3498}$ of that of the Sun, which agrees closely with that found by Bessel.

While the observations of the satellites of *Saturn* with the 15-inch refractor were directed mainly to the determination of the mass of *Saturn* and the elements of the orbits of the outer satellites, the observations with the 30-inch refractor with which we are now concerned aim at the determination of all the remaining elements of the Saturnian system, and with reference to the objects to which they are directed may be divided into three groups.

(1) The observations for the determination of the orbits of *Rhea*, *Dione*, *Tethys*, *Enceladus* and *Mimas*, the inner satellites of *Saturn*.

(2) The observations of *Hyperion*, made partly in comparison with the disc of the planet, and partly in comparison with *Titan* and *Iapetus*.

(3) The determination of the dimensions of the planet, and of the system of rings, and the angle of position of the line of the ansæ.

The author has made observations with these objects in view during the last four oppositions of *Saturn*, and he has now published some preliminary results relating to the first of the above-mentioned groups which possess considerable interest. It shows the great light-collecting power of the 30-inch refractor that in all the observations of the satellites, with the sole exception of those of *Hyperion*, it was found possible to make the measures in an illuminated field.

The magnifying power employed was 515.

This paper deals only with the orbits of *Rhea* and *Tethys* from measures connecting the two. In the reduction of the measures of distance made with the Repsold wire-micrometer, the value of one revolution of the screw at $t°$ centigrade is taken to be

$$= 12''{\cdot}7835 - 0''{\cdot}00025t.$$

The periodical errors of the screw are found to be quite insignificant.

With respect to the deduction of the elements of the satellites' orbits, substantially the same course is adopted as in the case of the observations with the 15-inch refractor. The polar co-ordinates directly observed are changed into rectangular co-ordinates, and these last are then compared with those calculated from approximate elements. In the comparison with observations for both satellites, circular elements in the plane of the ring (this last being assumed according to Bessel's determination) were taken as a starting point. The longitude and mean motion for *Rhea* were taken according to the author's own observations with the 15-inch, and for *Tethys* according to the older observations, while the mean elongations were calculated with the value of *Saturn's* mass $= \frac{1}{3500}$ of that of the Sun.

The assumed elements of the two satellites' orbits are the following; the epoch being 1886 March 22·0, mean time at Greenwich:—

		Tethys.	Rhea.
Longitude	E	165°30′·3	140°57′·3
Node on Ecliptic	Ω	168°0′·0	168°0′·0
Inclination on Ecliptic	i	28°10′·0	28°10′·0
Mean Tropical daily motion	λ	190°·69820	79°·690096
Mean Elongation (for $p = 9{\cdot}53887$)	a	42″·609	76″·169

In the calculations for the last epoch 1889, corrected longitudes were employed, viz. for *Tethys* $dE = -40'{\cdot}0$ and for *Rhea* $dE = -8'{\cdot}0$.

The author then gives a comparison between the results of observation and calculation. During the first three oppositions the observations were made by himself exclusively, but during the last opposition half of the observations were made by Herr Renz. Since the observations with the 15-inch refractor have given no sensible eccentricity for the orbit of *Rhea*, this orbit has been taken as circular, while for *Tethys*, where the older observations had indicated a small eccentricity, the quantities $e \sin P$ and $e \cos P$ have been introduced as unknown quantities.

Besides these the author introduces the two nodes, inclinations and longitudes of the epoch, as well as the mean elongation of *Rhea*, that of *Tethys* being supposed known, so that there are nine unknown quantities to be determined for each separate opposition.

The representation of the observations by means of the corrected values of the elements found from the equations of condition leaves nothing to be desired. The differences between the calculation and observation in 281 equations only in five cases amount to so much as 0″·2.

From the periodic time and mean elongation of *Rhea* the reciprocal of the mass of *Saturn* is found to be $3493{\cdot}0 \pm 0{\cdot}89$,

but a small systematic error in the measurement of distances would of course greatly affect this result.

The comparison of the elements obtained for the different years shows in reference to the longitudes of *Rhea* a good agreement, whereas the longitudes of *Tethys* show considerable differences which are not to be removed by an alteration in the assumed mean motion.

The author's observations in this respect are confirmed by those of Herr Bohlin, who deduces from the discussion of an older series of observations the existence of a periodical term in the longitude of *Tethys* which he represents empirically by A sin μt.

The eccentricity of *Tethys* is found from the equations of condition to be a small quantity of the same order as that of *Rhea*, and as the orbit of the latter was assumed to be circular, the eccentricity deduced in the case of *Tethys* can have little or no significance.

The fluctuations in the planes of the orbits of *Tethys* and *Rhea* shown by the solution of the equations of condition for the several years merit special attention.

These, in the first place, make possible a good determination of the position of *Saturn's* equator. It follows from a known proposition in the theory of perturbations, that the planes of the orbits of the inner satellites, while preserving a nearly invariable inclination with respect to *Saturn's* equator, must move on this latter plane so that the velocity of the node is nearly uniform, supposing, as is the case in the Saturnian system, that the compression of the planet is the chief cause of perturbation.

In fact, the results of these observations show that the elements of *Saturn's* equator may be so taken that the above condition for the satellites *Rhea* and *Tethys* is very nearly fulfilled. Thus for *Tethys*, if Bessel's determination of the elements of position of *Saturn's* equator be taken, it is found that the discrepancies in the values of the inclination of the orbit to the equator shown in different years considerably surpass the residual errors of the elements, and cannot be explained by the perturbations caused by the other satellites. If, on the other hand, proper corrections are applied to Bessel's elements, and the inclination of the satellite's orbit to *Saturn's* equator be taken $= 65'{\cdot}1$ there will be found a satisfactory agreement between the results of the several years.

Similarly, the elements of the orbit of *Rhea*, which have been obtained by means of the old refractor, can be shown to be consistent with each other in the several years if we suppose the inclination of the orbit to *Saturn's* equator to be $20'{\cdot}5$.

The author gives the following corrected elements of *Saturn's* equator referred to the equinox of 1886·2 : longitude of the node on the ecliptic $167°53'{\cdot}6$, inclination $28°{\cdot}2'{\cdot}0$.

From the longitudes of the node of the orbit of *Tethys* on

Saturn's equator, the author deduces that the yearly retrograde motion of the node on this equator is 72°·8.

Similarly, for the node of the orbit of *Rhea*, the yearly retrograde motion of the node is found to be 10°·2.

The motion of the nodes of *Tethys* and *Rhea* possesses a special interest through a comparison of it with the mean motion of the peri-Saturnium of *Titan*, for which the later observations, after allowing for precession and the perturbations caused by the Sun, have given the approximate value $\Delta P = 1800'' = 0°{\cdot}500$ per year. From this the author deduces an approximate value of the constant of compression for *Saturn*.

On the hypothesis already adopted by the author, that the masses of the satellites stand in a simple relation to their brightness, and relying on the photometric measures of Professor Pickering and the sufficiently well-known value of the mass of *Titan* $= \frac{1}{4700}$, he finds that the spheroidal form of the planet and the mass of the rings will account for about 62°·2 of the observed motion of the node of *Tethys*, and that the action of the other satellites will probably account for 3°·7, so that nearly 7° would be left unaccounted for. Similarly, the author estimates that the annual motion of the node of *Rhea*, due to the effect of the compression and the rings, would be about 8°·1, and that the effect of the perturbations caused by the other satellites would be about 1°·1, making altogether 9°·2, while the observations give 10°·2.

It will be observed that the difference between the calculated motion of the node and that deduced from the observations, is in both cases in the same direction, and the author thinks that at least in the case of *Tethys* the difference is larger than the possible uncertainty of the latter quantities.

The author is inclined to think that the difference between the observed and calculated values of the motion of the nodes may be explained in great part by supposing that the mass of the rings amounts to about $\frac{1}{300}$ part of the mass of the planet, but when the discussion of the observations of *Dione*, *Enceladus*, and *Mimas* is completed, we may expect that further light will be thrown on this point. J. C. A.

Professor Auwers' Researches on the Sun's Diameter.

Professor Auwers has continued his researches on the value of the Sun's diameter deduced from various series of observations, to some of the results of which attention has been directed in a former Report (*Monthly Notices*, vol. xlviii. p. 206). The paper now under consideration is No. III. of the series, and is published in the *Sitzungsberichte* of the Berlin Academy. It contains a discussion of the Greenwich transit observations of the Sun's diameter made during the years 1765–1810, by Maskelyne and

his assistants, and is carried out in that thorough and painstaking manner which is characteristic of all Professor Auwers' work. It will be remembered that, a good many years ago, Lindenau discussed Maskelyne's observations of the Sun, and the present investigation has been undertaken chiefly with a view to the extension of Lindenau's researches, so as to exhibit the results of a much larger number of observations. Instead, therefore, of contenting himself with making use only of those transits of the Sun's first and second limbs which were observed over the same threads, as Lindenau did (thereby restricting himself to but a small portion of the existing materials), Professor Auwers has determined afresh the intervals of the transit threads from appropriate star-transits, and has thus been able to utilise every observation in which transits of both limbs of the Sun were observed for determination of the horizontal diameter.

The observations under discussion are necessarily divided into two portions, *i.e.* those made before and after July 1772. At this date a new achromatic object-glass of 2·6 in. aperture was fitted to the transit instrument in place of the old 1·6 in. non-achromatic lens which was used previously. At the same time a new and more powerful eyepiece was brought into use. From his discussion of the observations made by Maskelyne and his assistants with the old object-glass, Professor Auwers finds that there is an apparent annual inequality in Maskelyne's values of the Sun's horizontal diameter, the observed diameter being greater than the mean in winter and less in summer (the range being about $0^s{\cdot}05$), and that this is borne out by the assistants' observations, so far as any result of this kind can be deduced from their somewhat meagre contributions. With regard to progressive change during the years under consideration (1765–1772), with the exception of the first two years—when the observers were new to the work, and made the diameter much too large—there is no fluctuation that would not be covered by the accidental errors of the observations. During the years 1772–1810, with the new and improved instrumental means, Maskelyne's observations still show an annual inequality of about the same magnitude and in the same sense as those made with the old object-glass. But it is somewhat remarkable that the assistants' observations made during this period show an inequality in exactly the opposite direction, *i.e.* they make the diameter smaller in winter than in summer, the range being about $0^s{\cdot}05$.

The progressive change, as exhibited in Maskelyne's observations made during the period 1772–1810, is also remarkable. Professor Auwers finds that the corrections to the diameters as given in the *Tabulæ Regiomontanæ* can be represented by the formula $-0^s{\cdot}243 \mp 0^s\,015(t-1790{\cdot}5)$, where the upper sign is applicable up to 1790·5, the lower after that date. Instead, therefore, of Maskelyne's observations giving progressively smaller values of the Sun's diameter during his whole observing life, as has hitherto been supposed, Professor Auwers' very exhaustive discus-

sion leads us to this result: that after the first two years (which gave a very large value), the observed diameter remained nearly constant for the period 1767–1772, then during the years 1772–1790 the diameter was continually decreasing, lastly from 1790–1810 the observations gave a diameter continually increasing. The minimum value in 1790 was 31′ 58″·13—about 1″ smaller than the value obtained from modern heliometer measures. The assistants did not individually observe through a sufficiently long series of years to afford a complete check on the results obtained from Maskelyne's observations as to progressive change in the observed value of the Sun's horizontal diameter. Professor Auwers has, however, discussed their observations thoroughly, determined their "personal equations" referred to Maskelyne's values of the diameter, and, generally, left nothing undone to render complete his discussion of the Greenwich series of diameters observed during the years 1765–1810.

The Moon's Physical Libration.

When, half a century ago, Bessel was enabled, by getting sufficiently free from other more pressing investigations, to employ the Königsberg heliometer for the purpose of investigating the Moon's physical libration, he entrusted the making of the observations to one of his assistants, H. Schlüter, who had already given proof of great skill and diligence by his observations for the determination of the parallax of 61 *Cygni* and of the positions of the stars in the *Pleiades*. After having accumulated a long series of sets of measurements extending over two years and a half, from April 29, 1841, to November 6, 1843, Schlüter fell ill and died, at the early age of 28 years, in March 1844, predeceasing Bessel by two years. At the end of 1844 the observations for the Moon's libration were resumed by Wichmann, and continued till January 1846. When, after Bessel's death, Wichmann undertook the investigation and prepared his paper "Erster Versuch zur Bestimmung der physischen Libration des Mondes aus Beobachtungen mit dem Heliometer" (published in vols. 26 and 27 of the *Ast. Nach.*), he confined himself at first to the reduction of his own observations and the determination of their results, and was the more justified in doing so, as the final results of the whole series of measurements could only be arrived at on condition that sufficiently approximate values of some of the unknown quantities had already been secured. It was, no doubt, Wichmann's intention to undertake the very laborious task of extending his investigation, so as to found it upon the whole series of available observations; but other occupations, and, later on, his failing health, did not allow him to accomplish more than part of the task. The results of Schlüter's measurements remained con-

sequently unknown, but lately they have been brought to light and investigated by Dr. Julius Franz in a very meritorious paper, published in vol. 38 of the *Königsberg Observations*: "Die Konstanten der physischen Libration des Mondes abgeleitet aus Schlüter's Königsberger Heliometer-Beobachtungen." After an exposition of the theory of the physical libration, in which he introduces some modifications and simplifications of the method followed by Wichmann, Dr. Franz explains the successive steps in the complicated reduction of the observations and the instrumental constants he has adopted; and, taking due advantage of Wichmann's preparatory computations, he deduces from the 158 sets of measurements the selenocentric ecliptical longitudes and latitudes of the observed spot Mösting A. In computing the corresponding tabular longitudes and latitudes and their differential coefficients, he has the advantage of starting with fairly approximate values, not only of the selenographical co-ordinates λ, β of the spot and of the inclination I of the Moon's equator, but also of the constant f, the ratio of the differences of the Moon's principal moments of inertia, which must be sufficiently well known, if the necessity for repeating a considerable portion of the computations is to be avoided. The comparison of the corresponding values of the selenocentric longitudes and latitudes furnishes, then, the 306 equations of condition, from which the corrections of the assumed values are obtained. Omitting, at first, those terms of the physical libration which are independent of the inequalities of the Moon's revolution, Dr. Franz deduces the following values:—

$$\lambda = -5^{\circ}\ 10'\ 19''{\cdot}0 \pm 7''{\cdot}9 \qquad I = 1^{\circ}\ 31'\ 22''{\cdot}1 \pm 7''{\cdot}3$$

$$\beta = -3\ 11\ 24{\cdot}0 \pm 5{\cdot}5 \qquad f = 0{\cdot}4878 \pm 0{\cdot}0278$$

the probable error of the deduced selenocentric longitudes being $96''{\cdot}1$, and of latitudes $61''{\cdot}4$, or geocentrically $0''{\cdot}44$ and $0''{\cdot}28$, the smallness of which testifies to the skill and care with which Schlüter's observations were made. Dr. Franz then introduces in the equations of condition those terms of the physical libration which are independent of the Moon's revolution, but represent the remnants of oscillations, which in some early state of the Moon's rotation may have been very considerable. The computation of these terms, however, shows that they are too small to be determinable from the available observations. As Schlüter's series is the only one, which is spread over a full period of the chief of these oscillations, this result is of considerable weight. Disregarding, therefore, these terms as insensible, Dr. Franz adopts the previously mentioned values of λ, β, I, f as the final ones, and deduces from them the values u, w, w'' of the Moon's physical libration as affecting the longitude, node, and inclination:—

$$u = +133''{\cdot}3 \sin g' - 21''{\cdot}8 \sin g + 17''{\cdot}6 \sin 2\omega$$

$$\sin \mathrm{I}\,.\,w = +11{\cdot}0 \sin 2(g+\omega) - 95''{\cdot}4 \sin g$$

$$w'' = +11{\cdot}0 \cos 2(g+\omega) - 95{\cdot}4 \cos g$$

where, in conformity with Hansen's tables, g' denotes the Sun's mean anomaly, g that of the Moon, and ω the departure of the Moon's perigee from the node.

Dr. Franz concludes his explanations with the proposal of determining the Moon's place by substituting observations of the spot Mösting A for those of the limbs.

When, in his paper "Ueber den astronomischen Gebrauch der Mondkarte," published 1837, in No. 337 of the *Ast. Nach.*, Mädler recommended the substitution of observations of spots for those of the limbs, he suggested Triesnecker B as the most suitable spot for the period from first to last quarter, and the spots Messier and Flamsteed for the earlier and later parts of each lunation. In 1855 and 1856 the method was tried in longitude determinations in the United States, and there is a paper about it to be found in the report of the Coast Survey for 1856, Appendix No. 25, "Report to the Superintendent of the Coast Survey, by Dr. C. H. F. Peters, on the method of substituting a lunar spot instead of the Moon's limb, in transits for determining the difference of longitude," the spot used being Messier, which is observable from about the fourth to the seventeenth day of each lunation. Mr. Neison has preferred Triesnecker A (or, as he has renamed it, Murchison A), which he calls in his book, *The Moon*, . . . "perhaps without exception the most distinct and conspicuous object within ten degrees of the centre of the Moon, and peculiarly well adapted to serve as a standard point for the origin of lunar measures and for the investigation of the Moon's real libration; its only rival is Mösting A, which, if perhaps slightly brighter, is surrounded by a bright region and is, moreover, slightly larger." According to a statement to be found in the *Selenographical Journal*, vol. 3, p. 84, Professor Winnecke had selected, presumedly for some good reason, the preceding of two small spots, south following Triesnecker, the chosen spot being in selenographical longitude $+2^\circ\ 22'$ and latitude $+3^\circ\ 19'$; but nothing further has been published about the observations there mentioned. Mösting A has at present the advantage that its selenographical co-ordinates are more accurately determined than those of any other lunar spot.

A. M.

The Orbit of Sappho.

During the past year Dr. R. Bryant has published the results of an investigation of the orbit of *Sappho* (80) from observations extending over the whole period from its discovery in 1864, to the opposition in 1888. This great task of calculation he has performed single-handed. Finding that a first solution correcting the elements only of *Sappho's* orbit left considerable errors, he has endeavoured to remedy this by introducing a correction to the mass of *Jupiter*, the solution of the equations leading to a change

in this element, which, while very large, is of no great weight. In seeking to mend matters Dr. Bryant was led, by a remark of Professor Adams, to consider the elements of *Sappho* as liable to a progressive change due to the action of the asteroids as a whole. The introduction into the equations of condition of terms involving the annual amounts of these changes was followed by a new solution for corrections. There now remained three normal places which stood out prominently in error. One of these has been brought into near accordance with computation by the discovery of an error in its deduction: and the other two depend on very few observations, each at one place, and during very few days, so that errors affecting them are probable. Dr. Bryant's enormous task could hardly be expected to have been quite free from errors of computation; he may be congratulated on having arrived at so fair a result, and we may hope that the revised ephemeris, which he promises for 1889, will be accurate enough to reduce the observations of *Sappho* which have been made during the opposition, in order to determine the solar parallax.

The Greenwich Ten-Year Catalogue for the Epoch 1880.

This catalogue was published towards the close of the year 1889, and is a complete summary of the stellar work with the transit circle at the Royal Observatory, Greenwich, in the years 1877–1886. It contains observations of practically all stars to the sixth magnitude, inclusive, which had not been observed at Greenwich since 1860; besides many others such as fundamental stars, stars near the zenith and horizon suitable for discussion of refraction, stars with large proper motion, close circumpolars, &c., which are continually observed at Greenwich, and stars required for comet or planet comparison, or other special purposes. The observations have been reduced to 1880·0 with Auwers' proper motions. The places of clock stars have been discussed in a separate investigation, by including only those cases where the same observer made observations for more than twelve hours, so that the mean clock correction for the group may be considered free from systematic errors in the assumed places of the clock stars. The corrections to the catalogue places thus indicated are found to be very small, and have not been applied. The correction to epoch for the catalogue was determined by a careful discussion of the solar observations made in the same ten years, and found to be insensible. For this discussion the observed N.P.D.'s of the Sun in the various years were all reduced to one system of R−D, flexure, co-latitude, and refraction corrections, the systems actually used in the various years having undergone several changes; and the refractions were finally corrected to correspond with the readings

of a more freely exposed thermometer than that previously used.

Similar systematic corrections in N.P.D. have been applied to the stellar observations where necessary, so that the catalogue is essentially homogeneous.

The observations of 691 circumpolar stars above and below the pole are compared and discussed in the introduction to the catalogue. The co-latitude found from the comparison of N.P.D.'s is 38° 31′ 21″·935, differing by only +0″·035 from the adopted value.

Cases of individual discordances have been examined with the greatest care, and every effort has been made to exclude mistakes in the reductions.

The total number of stars in the catalogue is 4059. H. H. T.

Standard Catalogue for the Southern Zones of the Astronomische Gesellschaft.

This catalogue,containing the places of 303 stars for the epoch 1885·0, has been prepared by Professor Auwers for use in the reduction of the zone observations extending from −2° to −23° declination to be carried out under the auspices of the *Astronomische Gesellschaft*. It is published in the *Astronomische Nachrichten*, Nos. 2890–91. The places of 135 of the stars occurring in the catalogue have been derived from the author's Fundamental Catalogue (Publ. *Ast. Gesell.* xiv. and xvii.), the Cordoba General Catalogue, a MS. Catalogue supplied by Dr. Gill, the Washburn Observations, and observations made at the U.S. Naval Academy at Annapolis. The places of the remaining 168 stars have been derived from the Karlsruhe Observations, Becker's Catalogue of Bradley Stars, and the Cape Catalogue for 1880, checked by later Cape observations. In general the proper motions adopted are those of the author's Catalogue, deduced from his re-reduction of Bradley's observations, but in certain cases a new determination of proper motion from all available materials was made. Professor Auwers considers that these star places, although merely provisional, are of considerable accuracy; they certainly agree well with those of the Fundamental Catalogue and other standard catalogues with which they have been compared for check. The system of right ascensions adopted is that of the Fundamental Catalogue; that of the north polar distances is identical with Professor Auwers' Mean System of N.P.D's. (*Ast. Nach.*, No. 1532), or with the system of the Fundamental Catalogue (which depends on Pulkowa) with the correction $+0''\cdot50-0''\cdot02\times\delta°$. The catalogue before us has evidently been prepared with care and skill, and by facilitating the reduction of the zone observations between −2° and −23° declination will, we hope, ensure the successful completion of that important work.

The Brussels Catalogue of 10,792 *Stars for the Epoch* 1865.

The principal object of this extensive work has been to determine the positions of stars having, or which have been suspected of having, large proper motions. It also contains the places of certain other classes of stars, such as multiple stars, moon culminators, &c. Stars down to the tenth magnitude appear to have been included in the work. The observations extend from 1857 to 1878, and were made with the transit instrument and mural circle of the Brussels Observatory, which were not altered in any way during this long period. The catalogue consists of two parts: the first gives the positions of the fundamental stars which have been used in the reductions; the second (forming the general catalogue) gives the positions of 10,792 stars of the classes referred to above.

With regard to the reductions, it may be sufficient to say that the clock errors and rates have been determined from observations of fundamental stars, below 50° 51′ north declination, given in the *Nautical Almanac*. The "zenith points" of the circle have been determined by reflection and direct observations or from observations of stars given in the *Nautical Almanac*. In those cases in which star places have been taken from the *Nautical Almanac*, it does not appear that any attempt has been made to reduce the different systems used in that work during the period 1857–1878 to uniformity. The reductions of the apparent places to the beginning of the year of observation have been made by means of "star constants" which, for stars of less than 80° declination, have been computed *only once* during the period under consideration, whilst for stars occurring in the British Association Catalogue, and of less than 60° declination, the star constants given in that work have been used. With regard to the reduction of the observations of each year to the adopted epoch 1865·0, the precessions have been computed for each year for the fundamental stars, whilst for the General Catalogue the precessions for 1865 have been used throughout, thus neglecting the effect of secular variation. No correction for proper motion has been applied to the observed places of stars in the General Catalogue. In the case of the Catalogue of Fundamental Stars, it is stated on page xii. of the introduction that no correction for proper motion has been applied, whilst on page xiv. it is stated that the proper motions of Auwers' Fundamental Catalogue have been used in the formation of these star places. It is, therefore, doubtful what has really been done.

It should, however, be pointed out that M. Folie states in the preface to the work that it is proposed to publish a supplement to this catalogue, giving corrections to the star places on account of inaccuracies in the reductions as they have actually been effected. This, doubtless, refers (amongst others) to the points

noticed above, but it would have been a much more convenient arrangement to have published these corrections as part of the catalogue itself, instead of letting them appear in a subsequent volume, without which the star places of the catalogue as it stands are not, we fear, of sufficient accuracy for the purposes of refined investigation.

The work before us is the outcome of an immense amount of labour, and gives the places of many stars which have received little or no attention at other observatories.

The Williams College Catalogue of North Polar Stars.

Professor Safford has recently published a catalogue of right ascensions of stars within 25° of the north pole, which he describes as an "attempt to strengthen the weak point of all our Standard Catalogues—the right ascensions of polar stars." The observations collected and discussed in this catalogue were made with the Repsold meridian circle of the Williams College Observatory (aperture of object-glass $4\frac{1}{2}$ inches) during the years 1882–1887. The results have been reduced to the epoch 1885·0 and exhibit the mean right ascensions of 261 stars deduced from observations made both above and below the pole. It has been Professor Safford's intention to make this catalogue mainly differential, the instrumental corrections depending on 11 stars of Auwers' Fundamental Catalogue (Publ. *Ast. Gesell.* xiv.), and the clock-errors being deduced mainly from the star places of the *Berliner Jahrbuch*. In the plan of the observations the use of Pond's method was entirely avoided, *i.e.* no star was considered as *determined* on any evening which had been required on the same evening for the instrumental corrections. During the year 1887 a chronograph was brought into use, being employed only for the observation of stars below 80° of declination. The instrumental corrections were still determined, as before, by the closer stars and the older method of observation, using clock corrections obtained by the same method. It was found that no large difference existed between the results of the two methods below 80°, when this course was followed. A very full and careful discussion of his results leads Professor Safford to the following conclusions :—

"First, that it is highly conducive to accuracy, systematic as well as in detail, to base a catalogue of polar right ascensions upon standard places in all hours of right ascension, rather than upon double transits alone. Second, that the introduction of meridian marks according to Struve (long-focus object-glasses, also suggested by Rittenhouse) is a great advantage to the primary catalogues. Third, that the eye-and-ear method should be retained as the standard within a narrow rather than a wide range of polar distance. Fourth, that modern meridian instru-

ments are subject to irregular small changes of position, which are not direct functions of the temperature; so that in all differential work it is better to keep a close watch upon clock-rate and instrumental adjustments rather than to trust the instrumental zero-points for more than two hours without re-determination of the most essential. Fifth, that the right ascensions here given are reasonably accurate. Sixth, that a thorough comparison of the chronographic and eye-and-ear method within a wide range, both of magnitude and declination, is desirable."

Orbits of Binary Stars.

Computers of double-star orbits have reason to be thankful to Professor Glasenapp, Director of the Imperial University Observatory, St. Petersburg, for bringing into notice some very elegant formulæ for determining the true orbit of a binary star. He follows the usual graphical method of obtaining the best possible apparent ellipse, and then, instead of determining the elements of the apparent orbit, he proceeds by a neat and simple method to evaluate the coefficients in the general equation of the ellipse,

$$\alpha x + \beta y + \gamma x^2 + \delta xy + \epsilon y^2 + 1 = 0;$$

assuming $y=0$, this reduces to $\alpha x + \gamma x^2 + 1 = 0$, the roots of which represent the ordinates of the intersection of the ellipse with the axis of x, which can be measured with a scale on the graphical representation of the apparent orbit. If we call these values x_1 and x_2 we get

$$\alpha = -\frac{x_1 + x_2}{x_1 x_2} \text{ and } \gamma = \frac{1}{x_1 x_2}.$$

Similarly if $x=0$, β and ϵ are found, and then by measuring the co-ordinates of two other points δ may be obtained. To determine these coefficients by the method of least squares is a long process. The elements of the true orbit are now determined directly from these coefficients by means of the elegant and singularly simple formulæ of M. Kowalsky. These were buried in a Russian paper published in the Proceedings of the Kazan Imperial University, and were practically useless until unearthed by Professor Glasenapp. In a pamphlet dedicated to M. Otto Struve, on the occasion of the Jubilee of the Pulkowa Observatory, Professor Glasenapp exhibits the orbits of OΣ 387, OΣ 149, OΣ 489, OΣ 413, OΣ 4, and OΣ 20, as obtained by this method. He also gives a list of personal equations in observing position-angles, and a table of the elements of the orbits of all OΣ stars hitherto calculated. T. L.

Variable Stars.

Mr. Chandler, to whose valuable catalogue of variable stars a reference was made in the last Annual Report, has continued the study of the phenomena presented by these objects, and has communicated the interesting results he has obtained to Gould's *Astronomical Journal* (Nos. 186 and 193), the journal in which his catalogue was itself published.

Taking his catalogue of 1888 as a basis, Mr. Chandler proposed to himself an investigation of the "relations which spring from the fact of periodicity; namely, the co-ordination of the lengths of the periods with the numbers of the variables, with their colour, with their range of fluctuation, with the forms of their light curves, and with the irregularities of their periods and of their light-variations," an investigation which led, briefly, to the following results:—

In regard to the first point he finds an excess of short periods, namely those under 20 days, while for the long-period variables a well marked maximum is indicated as lying about a period of 320 days. Turning to the question of colour, the evidence is distinct that the redness of a star is a function of the length of its period. The redder the tint, the longer the period. In respect of range of fluctuation, while it is probable that there is a dependence of range upon the duration of the period, the relation is not one of strict proportionality of range to period. Coming to the relations between the forms of the light curves and the periods, the author has tabulated the "Ratio of Increase to Decrease," taking unity to represent an equality in this respect, and values less or greater than unity to represent a greater or less rapidity of increase than decrease. From this it appears that "the average ratio for stars with periods less than 100 days is about 0·65; between 100 and 200 days it is slightly in excess of unity; it then declines as the periods lengthen, at first gradually, but in the neighbourhood of a year with extraordinary suddenness, recovering as quickly, until it again exceeds unity in the group of extremely long periods." In the case of the numerical laws of the perturbations of the periods, Mr. Chandler remarks that his researches are not yet complete, but that broadly, in the case of long-period variables, the irregularities are periodic in their nature, and in the case of those of short-period, secular and exceptional.

Mr. Chandler has handled his subject with great skill and ingenuity, and his papers are in every way worthy of careful examination and study. G. K.

M. Radau's Memoir on Astronomical Refraction.

M. Radau has recently published, in Tome xix. of the *Annales* of the Paris Observatory, a very complete memoir on the important subject of Astronomical Refraction, which deals with the theoretical as well as the practical side of the question, and contains complete tables in a convenient form suitable for the actual computation of refractions.

In the first chapter of the memoir the author discusses the constitution of the atmosphere, and the law according to which the temperature and density of the air diminish as we proceed upwards from the Earth's surface. M. Radau also discusses the influence of humidity on refraction, utilising, in this connection, the experiments of MM. Fizeau and Jamin.

In Chapter II. we find an analysis of the fundamental formulæ of the theory, as well as a discussion of the numerical value of the constant of astronomical refraction: the author adopting Bessel's value of the constant in the construction of his tables.

Chapter III. contains the explanation of the mathematical processes by means of which the definite integral which expresses the refraction is transformed so as to allow of its value being calculated numerically. For the relation between temperature and density the author adopts the hypothesis of Ivory, which makes the decrease of temperature proportional to that of density; the ratio of the two decrements being then constant along the path of the ray of light. This ratio, of course, varies from time to time, and enters into the refraction formulæ as a quantity depending on the readings of the thermometer and barometer taken at the time of observation.

In Chapter IV. M. Radau explains the construction of the tables which accompany the memoir. These appear to be arranged in a very convenient form for practical use, and to be sufficiently extended to obviate the necessity of troublesome interpolation, even at large zenith distances. The principal novelties are the correction for humidity, referred to above, and the correction for effect of gravity on the height of the barometer, which, of course, varies with the latitude.

Without actual trial it would be impossible to say whether these refraction tables are superior to those of Bessel for practical purposes: they are certainly more conveniently arranged for large zenith distances. But it must not be forgotten that the chief difficulty in determining astronomical refractions is a practical one, i.e. the difficulty of determining the temperature of the air which is applicable at the time of observation.

Professor Pritchard's Researches in Stellar Parallax by the aid of Photography.

In No. III. of the Astronomical Observations made at the University Observatory, Oxford (Clarendon Press, 1889), Professor Pritchard has given us a complete account of the very interesting series of Parallax Observations that he has made by photography. There can be little doubt that for the delicate work of stellar parallax as applied to the fainter stars the photographic method must ultimately prevail over all other methods by micrometers or by heliometers. It is impossible to study the present volume or to examine the plates themselves without finding ample evidence in support of this conclusion. In the first place, as Professor Pritchard remarks, the photograph will just as easily provide us with four comparison stars as with two, and the subsequent measurements upon the plate afford results which are to say the least quite as good as the very best measurements of star distances that can be obtained by any other method.

Nearly half of the work before us is occupied with a most elaborate series of measurements of 61 *Cygni* with four comparison stars. As both components of the double have been independently considered, we have, in fact, eight measurements of the parallax. This renowned star has been attacked by almost every investigator of star distances, and opinion was gradually converging to the belief that the parallax of 61 *Cygni* could not be far from midway between 0″·40 and 0″·50. But when the high authority of Professor Asaph Hall could be cited as evidence that the star must be nearly twice as far off as these figures would indicate, it became manifest that there was still ample room for such a research as that of Professor Pritchard.

To show the value of the photographic method as applied at Oxford, we may cite the following table of results:—

Star's Name.	Mag.	Relative Annual Parallax.	Probable Error of Parallax.	Probable Error of One Complete Measure of Distance.
		61$_1$ *Cygni*.		
		″	″	″
D.M. +37° No. 4189	7·9	+0·4294	±0·0162	±0·091
„ +38° „ 4336	8·8	+0·4414	±0·0222	±0·115
„ +37° „ 4175	9·0	+0·4448	±0·0212	±0·102
„ +38° „ 4348	9·5	+0·4193	±0·0182	±0·089
		61$_2$ *Cygni*.		
D.M. +37° No. 4189	7·9	+0·4250	±0·0176	±0·099
„ +38° „ 4336	8·8	+0·4508	±0·0191	±0·100
„ +37° „ 4175	9·0	+0·4320	±0·0190	±0·088
„ +38° „ 4348	9·5	+0·4303	±0·0178	±0·104

These figures seem to justify the remark that "the four comparison stars probably belong to a remote system not containing 61 *Cygni*." The smallness of the probable error speaks sufficiently for the accuracy of which the method is capable.

The other stars discussed in this volume are μ *Cassiopeiæ*, *Polaris*, α *Cassiopeiæ*, β *Cassiopeiæ*, γ *Cassiopeiæ*, and α *Cephei*, among which β *Cassiopeiæ* alone seems to have a parallax which attains the value of a tenth of a second. The table p. 137, in which all the results are epitomised, gives incidentally a striking illustration of the advantage which the photographic method has over that by micrometers. In the latter case 300″ is about as great a distance as can be conveniently measured, while the photographic plates enable distances of even 1380″ to be dealt with. Of course there would be no point to be made in this respect in favour of the photographic method over that by the heliometer.

It seems that this work, so successfully carried out by Professor Pritchard and his able assistants at Oxford, must be the initiation of a new method in the study of the important subject of star distances. R. S. B.

Determination of the Motions of Stars in the Line of Sight by means of Photography.

Professor H. C. Vogel, who was one of the first to confirm the recession of *Sirius* from the solar system after the original observations in 1868, has recently entered upon, with the assistance of Dr. Scheiner, an investigation of the motions of all the brighter stars visible at Potsdam, by the method of Photography. Those observers who have worked at these delicate comparisons by eye will be the first to welcome a method which diminishes greatly the uncertainties which may come in from atmospheric disturbances.

The consistent agreement of Professor Vogel's preliminary results seem to show that the difficulties of obtaining trustworthy simultaneous photographs of the brighter stars, together with a terrestrial bright line for comparison of position, have been successfully overcome, and that his method is capable of considerable accuracy, and that consequently the results which we may look for from Potsdam will have great value, and be deserving of confidence.

As it was important to obtain the spectrum on as extended a scale as possible of a large number of stars without an exposure inconveniently long, Professor Vogel wisely determined to limit the part of the spectrum on the plate to the region for which the ordinary silver bromide gelatine plates are most sensitive—namely, to a small distance on each side of G, from λ 451 to λ 417; and to employ as the line of comparison the hydrogen line H γ, which falls near G.

One of the most important conditions to be observed in such an investigation is the absolute rigidity of the comparison spectrum relatively to that of the star. To avoid the danger of shift from flexure, in different positions of the telescope, when the comparison spectrum is connected directly with the spectroscope or its attachments, it had been found desirable to introduce the artificial spectrum within the tube of the telescope itself, and further to diminish the risk of parallactic displacement of the artificial spectrum, to place the source of light at some distance from the slit. Professor Vogel places his vacuum-tube at a distance of 40 cm., and though it is not actually fixed within the telescope-tube, it is so close to the end of the tube as to be practically free from the possible effects of flexure in the spectroscope and its attachments. These have been constructed, both in respect of material and of form, so as to give great stability to the whole instrument, which is attached to the eye-end of the Potsdam refractor.

The optical part, constructed by Steinheil, consists of two Rutherfurd prisms, of very transparent glass. The objectives of the collimator and of the camera are made as thin as possible, and are corrected for G. The apparatus is fully supplied with the means for all the necessary adjustments, not only in respect of focus, but also of the direction of the optical axis of the collimator with that of the telescope. A small breadth, usually from 0·2 to 0·3 mm. is given to the spectra by such an alteration of the clock motion as is needful to make the star's image move slowly through the necessary distance within the slit.

The effects of temperature changes have been carefully examined, and tables of corrections provided by which the necessary alterations of focus can be made, when the change of temperature during the exposure, usually about one hour, exceeds 2°; within this limit no sensible falling off of sharpness can be detected. Practically some time is required for a change of external temperature to reach the prisms, and special precautions are taken that change of temperature does not affect the position of the hydrogen line relatively to the star's spectrum. The slit is usually made very narrow, from ·02 to ·03 mm., corresponding to an angular value of 10 to 15 seconds.

The spectra, which are about 3 to 4 cm. in length, are measured under a suitable microscope with a magnification of from 7 to 35 times.

Within this small region of the spectrum, in the case of Capella, no fewer than 250 lines have been measured, and the coincidence of nearly all of them with solar lines confirms the conclusion already arrived at by Huggins in 1882, that this star is almost identical in composition and in present temperature with our Sun. Up to the present time about 170 photographs have been taken of about 50 stars. These photographs have been measured, but some time must elapse before the final conclusions as to the motions, and changes of motions, of the stars are

reached. The results in the case of five stars have been given provisionally; these show the close agreement of photographs taken on different days, and the high degree of accuracy to be expected from this work. The motions are given in geographical miles, + represents recession, and — approach.

α Aurigæ.

1888, Oct. 22	+3·5	1888, Dec. 1	+3·1
24	+3·6	13	+3·2
25	+3·4	1889, Jan. 2	+3·3
28	+3·2	Feb. 5	+4·0
Nov. 9	+3·7	Mar. 6	+3·8

α Tauri.

1888, Oct. 28	+6·4
Nov. 10	+6·7
Dec. 4	+6·3

α Ursæ Minoris.

1888, Nov. 14	−3·2
Dec. 6	−3·8

α Persei.

1888, Dec. 5	−1·5
10	−1·6

α Canis Minoris.

1888, Dec. 8	−1·5
29	−1·6

It is of interest to compare these results with those obtained under the great difficulties of eye observation at Greenwich: —

	Vogel, English Miles.	Maunder, English Miles.		Vogel, English Miles.	Maunder, English Miles.
Capella	+17·1	+22·5	α Persei	−7·2	−22·5
Aldebaran	+30·3	+31·6	Procyon	−7·2	+ 3·8

A result of great interest, which had been indeed already foreshadowed by the Greenwich Observations, has come out of Professor Vogel's photographs, in the case of the variable star *Algol*. Six photographs of *Algol* taken in 1888 and 1889 show a distinct change of motion to be connected with its light period, namely that before minimum it is receding at the rate of 24·4 English miles per second, while after the minimum has been passed the star approaches us with the velocity of 28·6 miles per second. From these velocities it follows that the system of *Algol* is approaching our system at the rate of 2·3 miles per second, and that the visible star has a velocity in its orbit of 26·3 miles per second.

From these results, which Professor Vogel wishes to be regarded as provisional only, he deduces the following approximate data of the *Algol* system :—

Diameter of *Algol*	1,061,000 English miles.
Diameter of dark companion	830,300 „
Distance of centre	3,230,000 „
Motion of *Algol* in orbit	26·3 miles per second.
Motion of companion	55·4 „
Mass of *Algol*	$\frac{4}{5}$ of Sun's mass.
Mass of companion	$\frac{2}{5}$ „
Translation of System towards the Sun	2·3 miles per second.

Professor Vogel has assumed that both bodies have the same density, so that their masses are directly as their volumes. Professor Vogel is not unaware of many points of difficulty in connection with this hypothetical state of things in the system of *Algol*, and its relation to the known phenomena of the star's light-changes. He refers to one point, namely, the apparently great difference of temperature of two bodies not differing more greatly in mass, one intensely hot, the other dark to us. He does not think it necessary, however, to regard the companion as absolutely dark, but only relatively so to us, but it may be still glowing and emitting light, provided its brightness is less than $\frac{1}{80}$ of that of *Algol* itself. Professor Vogel calls attention in this connection to what we know of *Sirius* and his dark companion.

The Greenwich Observations give a similar difference of rate of motion at the two elongations, namely, 46 miles; Vogel's difference is 53 miles; but the motions do not so nearly balance each other, leaving a large motion of approach of the whole system.

It need scarcely be said that Professor Vogel's final results on *Algol* and the other stars photographed at Potsdam will be awaited with much interest. W. H.

Photographic Photometry.

The readiest and most effective means of determining the magnitudes of stars from an examination of the discs impressed on a sensitised film is a problem that has received much attention during the past year, and contributions to the literature of the subject have recently been made from the three observatories of Harvard, Stockholm, and Potsdam. It will, perhaps, be generally felt that in a problem of such importance and such interest the last word has not yet been said.

Professor Pickering's method is described, and his results are given in vol. xviii. of the *Annals* of the Harvard Observatory. The vigour and enterprise which characterise the direction of that institution have enabled the director to give no less than three catalogues of magnitudes, embracing, on the whole, some 2500 stars. The first of these catalogues gives the photo-

graphic magnitudes of all the stars brighter than the fifteenth magnitude, within one degree of the pole. The method employed in the determination of these magnitudes was to compare the trail of a star, obtained under various conditions, with the trails of those stars whose magnitude was sought.

The second catalogue contains the magnitudes of many of the stars in the *Pleiades* group. Here the method of trails was inappropriate, and the magnitude was derived by comparing the discs of two stars in the *Hyades*, as given by exposures of known but various lengths, with those impressed on the *Pleiades* plates. An additional check on the accuracy was supplied by means of a catalogue of 14 standard stars, whose magnitudes had been determined by the wedge photometer.

The third catalogue is deduced by the method of trails. It gives the photographic brilliancy of 1131 stars generally brighter than the eighth magnitude, situated near the equator. The object of this investigation is to furnish a catalogue free from systematic error with which stars in all parts of the sky can at any time be conveniently compared. A comparison between the photographic and photometric magnitudes of 500 of these stars leads to the conclusion that for stars brighter than the fifth magnitude the numerical photographic magnitudes are in excess by one unit. The photometric and the photographic scales continually approach each other as the stars grow fainter, till at 8·5 they are coincident. Here the scales cross and the photometric magnitudes are numerically greater than the photographic. Professor Pickering has given both the photographic magnitude and the same quantity reduced to the photometric scale.

The contribution from the Potsdam Observatory has been translated and published under the auspices of the International Committee for Promoting the Photographic Chart of the Heavens. It is confined to the discussion of the magnitudes of stars in the *Pleiades* as impressed on plates taken with a chemically corrected object-glass by Dr. Scheiner, and with the reflecting telescope of the Herény Observatory, supplemented by some photographs of the artificial stars in a Zöllner photometer.

Dr. Scheiner has not been fortunate in his negatives. The images on the *Pleiades* plates are in neither instance circular, probably from want of accurate driving, but Dr. Scheiner believes that by measuring both the major and minor axes of the resulting ellipses, and using the square root of the product in his researches, he has effectually removed any source of error from this cause. The principal results of the inquiry are twofold: first that the increase of the diameter of the disc varies as the square root of the time of exposure, and secondly that a simple linear relation exists between the observed diameter and the magnitude, or

$$m = a - bD,$$

where a and b are constants to be determined from each plate if accuracy be required; but, as a rule, Dr. Scheiner believes

that a simple inspection of the stellar discs, aided, it may be, by some mechanical contrivance to assist the memory, will be sufficient to give the magnitude with a fair amount of approximation.

The third contribution to this subject is from Dr. Charlier, of Stockholm, whose aim is to determine the form of the function which expresses the connection between the photographic brilliancy of a star and its photographed image in such a manner as to ensure a coincidence as far as possible between the photographic and photometric magnitudes. The research, which is conducted with great care, is founded upon two series of plates, made with a chemically achromatised object-glass of 81 mm. aperture and 100 cm. focal length. In one series of photographs the *Pleiades* group is taken on four plates, with times of exposure varying from 13 to 180 minutes, and thus stars of great difference in brilliancy have been photographed in the same time on the same plate; in the second series *Polaris* is photographed on the same plate with different exposures, and therefore the light is constant and the time variable.

The formula employed in the reduction of the observations differs from that adopted by Dr. Scheiner and more nearly resembles that suggested by Professor Pritchard in 1886, inasmuch as both agree that a simple linear expression is not admissible, and prefer a logarithmic function. Dr. Charlier expresses the relation between the magnitude m and the diameter D by the equation

$$m = a - b \log D,$$

and remarks that where only one instrument and one kind of plate are concerned b may be assumed constant, and for the Stockholm apparatus he finds from the *Pleiades* series

$$b = 6{\cdot}75.$$

If the sensitiveness of the plate be supposed to remain constant and the observations are made only at those times when the atmospheric conditions are at their best, a may be regarded as a function of the time of exposure, and Dr. Charlier proposes the following form:

$$a = 17{\cdot}2 + 1{\cdot}69 \log t,$$

t being expressed in minutes. The value of a, however, given by this formula is not that used in the subsequent reductions, but a value has been computed for each plate by inserting Lindemann's photometric magnitudes m of the 52 Besselian stars in the formula

$$a = m + 6{\cdot}75 \log D.$$

The *Polaris* series of negatives is well adapted for the discussion of the variation of the diameter with the time of exposure, and Dr. Charlier thinks the evidence warrants the conclusion that

this increase varies as the fourth root of the time. This result, which disagrees with that mentioned above as found by Dr. Scheiner, is in accord with that given by Prof. Pritchard.

Adopting, however, this law of increase, Dr. Charlier finds that his observations of measured diameter can be reduced consistently to photometric magnitude by the formula already given, or by

$$m = 17{\cdot}2 - 6{\cdot}75 \log . \frac{D}{\sqrt{t}}.$$

We are thus in possession of the photographic magnitudes of the stars in the *Pleiades* determined by three different methods. In one of these series, that of Dr. Scheiner, the inquiry is limited to the brighter stars of the group only, and it is owing to this limitation that he has been able to use so simple a formula as that quoted. Dr. Charlier has shown that when stars greatly differing in brilliancy are compared the employment of such a formula is misleading. The other two series, however, viz. those of Harvard and Stockholm, which contain the fainter stars of the group, are available both for mutual comparison and also for comparison with the magnitudes assigned to the same stars by M. Wolf.

The comparison of the scales of Charlier and Pickering is not altogether satisfactory, and suggests the possibility of systematic error in one or other of the two series. For stars of the tenth magnitude the scales coincide, but to fainter stars Prof. Pickering ascribes a larger, and to brighter stars a smaller, numerical magnitude than does Dr. Charlier. This peculiarity, however, is not noticeable in the comparison of the Harvard fourteen standard stars, referred to above, and from this fact Dr. Charlier concludes that the cause of the systematic error will not be found in the Stockholm observations. From a comparison of either series with the magnitudes assigned by M. Wolf, it would seem that there is no reason to conclude that stars much fainter than 15·5 magnitude have yet been photographed. W. E. P.

The Photographic Chart of the Heavens.

The Permanent Committee, appointed by the Astrophotographic Congress of 1887, held their first meeting at the Paris Observatory in September of the past year, under the presidency of Admiral Mouchez, and the proceedings have been published, like the *Bulletin*, through the liberality of the Académie des Sciences.

The meeting was attended by eighteen members of the committee:—MM. Anguiano, Baillaud, Bakhuyzen, Beuf, Christie, Cruls, Dunér, Paul Henry, Prosper Henry, Janssen, Kapteyn,

Loewy, Mouchez, Pujazon, Rayet, Tacchini, Trépied, and Weiss; also by twenty-one other astronomers, specially invited.

The *séances* were opened on September 16 with an address from Admiral Mouchez, after which MM. Christie and Dunér were appointed vice-presidents, and MM. Bakhuyzen and Trépied secretaries.

A provisional programme of questions for discussion was laid before the committee, and the important subjects of the distribution of the work among the different observatories and the selection of test-objects were submitted to a special committee consisting of MM. Beuf, Christie, Cruls, and Loewy.

The results of the seven *séances* which were held are contained in a series of twenty-eight resolutions, of which we may mention the more important.

The zones assigned to the several participating observatories are as follows:—

	Latitude.	Zone.
	North.	
Helsingfors	+60° 9′	+90°–70°
Potsdam	+52 22	70–58
Oxford	+51 45	58–48
Greenwich	+51 28	48–40
Paris	+48 50	40–32
Vienna	+48 13	32–24
Bordeaux	+44 50	24–18
Toulouse	+43 37	18–12
Catane	+37 30	12– 6
Algiers	+36 48	6– 0
San Fernando	+36 27	0– 6
Chapultepec	+19 26	– 6–12
Tacubaya	+19 24	12–18
	South.	
Rio de Janeiro	–22 54	–18–26
Santiago	–33 26	26–34
Sydney	–33 51	34–42
Cape of Good Hope	–33 56	42–52
La Plata	–34 55	52–70
Melbourne	–37 50	70–90

Twelve test-objects were selected, all of which are situated near the equator, at intervals of about two hours of right ascension. In addition to these the *Pleiades*, *Præsepe*, and a group in *Cygnus* were selected for the use of the more northern observatories.

It was decided that the field of the telescope available for measurement should be 2° square; that the photographic plates employed (which are to be of plate glass) shall be 160 mm. ($6\frac{1}{4}$ inches) square and the réseaux 130 mm. ($5\frac{1}{8}$ inches) square, with the lines 5 mm. apart.

Much consideration was given to the important question of fixing the time of exposure for the second series of plates, so as to ensure that they shall contain stars to magnitude 11·0, and it was eventually resolved to determine the time necessary to photograph a star of magnitude 9·0 of Argelander's scale, and then multiplying that by 6·25 will give the exposure for magnitude 11·0. Another important resolution was passed respecting the catalogue plates to the 11th magnitude, viz. that there shall be two exposures on each plate: the first to give stars to magnitude 11·0, and the second with one quarter the duration of the first, and with a displacement of 0·2 to 0·3 mm. as a check against defects and spurious stars.

Two numbers (3 and 4) of the *Bulletin* of the Permanent Committee have been published during the past year, which contain several papers of interest and importance. Professor Bakhuyzen contributes one on the measurement of the plates by the method of rectangular co-ordinates, in which he gives the results of its application from the measurement and reduction of a plate taken by the Brothers Henry. The places obtained compare very favourably with meridian places. Professor Vogel, who has generously offered to construct and verify all the réseaux required, contributes one or two papers on the subject of the réseaux and the measurement of the plates. Professor Kapteyn has suggested in the fourth number the expediency of taking the catalogue plates with three exposures at intervals of six months, and with a slight displacement on each occasion. By this means he considers data could be secured for determining the stars' proper motions and parallaxes. A further important and valuable paper by Dr. Scheiner in the same number, on the application of photography to the determination of stellar magnitudes, has been noticed on another page.

The past year has seen the generous gift of $50,000 to the Harvard College Observatory from Miss Bruce, of New York, for the construction of a photographic telescope of 24 inches aperture and 11 feet focal length. With this instrument Professor Pickering has proposed to make a photographic chart of the heavens somewhat different in character from that decided on by the Paris Congress. This telescope will differ from other large instruments in the construction of its object glass, which will be a compound lens of the form known as a photographic doublet. A portion of the sky covering 25 square degrees will be photographed on each plate on a scale of one minute to a millimetre, and it is contemplated that stars of the 16th magnitude, and even fainter, will be photographed by it.

We cannot doubt that under the able and energetic direction

of Professor Pickering this telescope will produce results of the highest interest and value to astronomy.

Spectroscopic Astronomy in 1889.

The Sun.—Mr. Lockyer has presented a second report to the Solar Physics Committee on the observations of Sun-spot spectra made at South Kensington. The previous report covered the period from November, 1879, to August, 1885, and included 700 observations of spot-spectra. The present report carries on the record to February, 1888, but as the spot activity of the Sun was rapidly declining during this period, only 150 observations could be secured. These, however, quite confirm the conclusion arrived at by Mr. Lockyer in 1886 that "as we pass from minimum to maximum the lines of the chemical elements gradually disappear from among those most widened, their places being taken by lines of which we have at present no terrestrial representatives," and especially is this so for the region between F and *b*.

A paper read before this Society by the Revs. S. J. Perry and A. L. Cortie, in which the region C to D, as seen in the spectrum of a spot at the time of maximum, was compared with the same region in another spot at the time of minimum, fully confirms Mr. Lockyer's inference with regard to the lines of known metals, and especially of iron; but no special difference was noted in the behaviour of the unidentified lines in the two spots.

A fresh determination of the rotation period of the Sun by the spectroscopic method has been effected by Mr. Henry Crew, 26·23 days being obtained as the value of the sidereal rotation. Mr. Crew calls attention to the fact that this is considerably longer than the period derived from observation of the faculæ or spots, and that this again is longer than the period which some observers have inferred from the variation of the magnetic elements. He therefore makes the suggestion that these different values may be derived from different solar levels, and that the angular velocity of the lower levels may be greater than that of the higher.

The Telluric Spectrum.—M. Janssen has confirmed the conclusions which he drew from the results of his expedition to Les Grands Mulets in 1888, that the oxygen lines of the telluric spectrum are wholly due to the influence of our own atmosphere, and in no degree to that of the Sun, by a series of observations of the spectrum of an electric light placed on the Eiffel Tower as viewed from the Observatory of Meudon.

The Aurora.—Dr. Huggins has communicated to the Royal Society an important paper on the wave-length of the principal line in the spectrum of the Aurora, showing cause for regarding

its value as $\lambda = 5571$. Mr. Lockyer, who had identified the line with the fluting of manganese at λ 5580, has replied to the effect that his inference had been justified by such facts as had been accessible to him at the time, that the two lines are undoubtedly very near to each other, and that a direct comparison of the two spectra at the earliest opportunity is imperatively called for.

Saturn's Ring.—The question of the presence of bright lines in various planetary and stellar spectra has come into great prominence during the past year, and there is yet great difference of opinion between different observers. With regard to the spectrum of *Saturn's* Ring, Mr. Lockyer considered that he had obtained some indications in a photograph of the existence of such bright lines, but the evidence was not sufficiently strong for him to announce their presence as an undoubted fact. Dr. Huggins, on the other hand, could obtain from a photograph which he took nothing but an ordinary solar spectrum, and direct eye observation with a spectroscope attached to the great equatoreal of the Lick Observatory led Mr. Keeler to a similar conclusion.

Uranus.—Mr. Albert Taylor has examined the spectrum of this planet in great detail by means of a spectroscope mounted upon Mr. Common's five-foot reflector, and it was his decided impression that bright flutings as well as dark absorption bands formed a marked feature of the spectrum. His opinion has not, however, received any support either from the photographs Dr. Huggins has taken or from the eye-observations made by Mr. Keeler at the Lick Observatory.

Bright Lines in Stellar Spectra.—Mr. Espin has continued his search for stars with remarkable spectra and has been rewarded by further discoveries of bright lines in the spectra of a number of variable stars when near their maxima: *R Leonis*, *R Hydræ*, χ *Cygni*, *R Andromedæ*, and *S Cassiopeiæ*. The foregoing stars are all of Secchi's third type, but the observers at the Lick Observatory have suspected the presence of similar lines in the spectra of two stars of the fourth type, *U* and *V Cygni*, and when these stars were far removed from their maximum. It is therefore particularly desirable that these stars should be carefully watched as they increase in brightness. Mr. Keeler also finds that he is able to break up the apparently continuous spectra of stars of the type of the Wolf-Rayet stars in *Cygnus* into "an extremely complicated range of absorption bands and faint bright lines." These observations are of especial interest at the present time from the remarkable accord which they present with the views Mr. Lockyer has put forward in the development of his meteoritic theory.

A remarkable form of spectrum has been discovered by Professor Pickering in that of the star *Pleione*, for the F line consists in this case of a narrow bright line superposed on a broader dark line, the other hydrogen lines showing some indications of a similar character.

Spectroscopic Surveys.—The Third Report of the Henry Draper Memorial announces the practical completion of two branches of the work undertaken with the funds provided by Mrs. Henry Draper, the photographic survey of the spectra of all stars north of 25° S. Dec. having been effected on a twofold scale, the one survey including all stars brighter than the 7th magnitude, the other including stars two magnitudes fainter. The Bache 8-inch doublet employed in this work has been transferred to a station near Chosica in Peru, and similar surveys for the stars down to the South Pole have been commenced. Already nine stars of the Wolf-Rayet type have been discovered, whilst *θ Muscæ*, like *φ Persei* and *γ Cassiopeiæ*, has been found to show the F line bright.

A spectroscopic survey of the southern heavens by direct observation has been undertaken at the Melbourne Observatory. Two lists of spectra observed with a Maclean spectroscope on the 8-inch equatoreal in the course of a preliminary reconnaissance have already been published, but a more powerful spectroscope will be used in connection with the 4-foot reflector later on.

Motion of Stars in the Line of Sight.—Besides the routine work carried on at the Royal Observatory, Greenwich, and the observations made by Mr. Seabroke at Rugby, some valuable results in this field of spectroscopy have been secured by Professor Vogel, which are, however, referred to on another page. Some remarkable illustrations of the principle of observation have been discovered by Professor Pickering, for he found the K line in the spectrum of *ζ Ursæ Majoris* to be double at intervals of fifty-two days. The present explanation of this strange variation is that the star is really a double star, of which the components are practically equal in size, and too close to have been separated hitherto by the means at our command. In their revolution round their common centre of gravity, the two stars are sometimes both moving perpendicularly to the line of sight—when the lines of the combined spectrum are seen in their true positions—and sometimes one is approaching the Earth whilst the other recedes, giving rise to a displacement of the lines of the two spectra in contrary directions, and hence to an apparent doubling of the lines. *β Aurigæ* and *b Ophiuchi* have spectra exhibiting a similar and periodic change.

The Great Nebula in Orion.—Dr. and Mrs. Huggins have communicated to the Royal Society a very valuable paper on the visible and photographic spectrum of this nebula. Besides determining the places of thirty-six lines, the authors have arrived at the following three principal conclusions: (1) It does not appear that magnesium is represented in the nebular spectrum. (2) The two photographs taken in 1888 gave an entirely different spectrum from one taken over a different but still adjacent part of the nebula about a year later. (3) Two of the trapezium stars seem to give the same groups of bright lines as

the surrounding nebula, and are therefore "physically bound up with it, and are very probably condensed out of the gaseous matter of the nebula."

Mr. Albert Taylor has also observed the visible portion of the spectrum, and added several new lines to those previously recognised.

Limit of Solar and Stellar Light in the Ultra-Violet Part of the Spectrum.—Dr. Huggins has found, as is stated more at length in the report of his Observatory, that the photographic spectra of *Vega* and of the Sun suffer an abrupt weakening at about λ 3000, and apparent total extinction at λ 2970. The observations of Cornu, Hartley, and quite recently of Liveing and Dewar, appear to show that the definite absorption to which the very rapid extinction of the solar spectrum is due has its seat in the Earth's atmosphere, and not in that of the Sun, and is caused by one of its gaseous constituents, probably oxygen, and not by aqueous vapour. Dr. Huggins thus confirms this conclusion by showing that the limit of the spectrum is practically the same for *Vega* as for the Sun. E. W. M.

Professor Spoerer's Researches on Sun-spots.

Professor Spoerer, who has devoted much attention not only to the current state of the solar activity, but also to the early records of Sun-spots, published early in 1889 two important papers on the results of his researches in the latter field. The two papers are entitled respectively "Ueber die Periodicität der Sonnenflecken seit dem Jahre 1618," communicated to the Royal Leopold-Caroline Academy, and "Sur les différences que présentent l'hémisphère nord et l'hémisphère sud du Soleil," appearing in the number of the *Bulletin Astronomique* for February 1889. The conclusions arrived at in these two papers may be summarised under the three following heads:–

First. These earlier observations afford us many examples of the operation of the "law of zones;" that is to say, a little before a minimum spots are only seen in low latitudes, at about the time of mininum spots near the Equator cease to appear, whilst a fresh series of spots break out at a great distance from it, and from thenceforward to the next minimum the mean heliographic latitude of the spots tends to decline continuously, until at length spots are again seen only in the vicinity of the Equator. This law held good, Professor Spoerer shows, for the minima of 1619, 1755, 1775, 1784, 1833, and 1844, and to some extent for that of 1645.

Second. Though in general a predominance for a time of spots in one hemisphere is sooner or later balanced by a corresponding predominance in the other, this is not always the case, and Professor Spoerer calls attention to three periods in which the southern hemisphere was decidedly the more prolific. The

first was from 1621 to 1625, there being no northern spots in 1621 and 1622, and but few in the three following years. Another is the present period, for from 1883 to the present time the southern spots have been nearly twice as numerous as the northern. But the third was the most remarkable, for from 1672 to 1704 we have no record of any northern spots at all; and Cassini and Maraldi expressly declared on the appearance of a northern spot in 1705 that they did not recollect ever to have observed a spot in that hemisphere before. Northern spots continued to be infrequent until 1714.

Third. For a period of about seventy years, ending in 1716, there seems to have been a very remarkable interruption of the ordinary course of the spot cycle. In several years no spots appear to have been seen at all, and in 1705 it was recorded as a most remarkable event that two spots were seen on the Sun at the same time, for a similar circumstance had scarcely ever been seen during the sixty years previous. So far as the observations go, the "law of zones" also seems to have been in abeyance, for no regular drift was apparent, the mean latitude being low—about 8° or 9°—during the entire time.

Professor Spoerer is still continuing his researches into ancient Sun-spot records, and hopes to be able to examine the manuscripts of Plantade (1705–1726) and of Flaugergues (1794–1830). E. W. M.

Jupiter.

The four following memoirs on the physical appearance of *Jupiter* have recently appeared:—

(1) "Études sur l'Aspect Physique de la Planète Jupiter," par Dr. F. Terby (vol. xlix. of the *Mémoires Couronnées* of the Royal Academy of Sciences of Belgium). This memoir, which is illustrated by 100 sketches of the planet made by means of a telescope of $3\frac{1}{2}$ inches aperture, contains the author's observations from 1882 to 1885, and is in continuation of an earlier paper appearing in vol. xlvii. of the same publication. The special feature of the memoir is the attempt to identify the details of the planet's surface in successive rotations, a work which Dr. Terby believes he has been able to accomplish more successfully in 1887, when he had the assistance of his present refractor of 8 inches aperture.

(2) "Observations of the Planet Jupiter." By Dr. Otto Boeddicker (Royal Dublin Society, *Scien. Trans.* vol. iv. series 2, March 1889). These observations comprise 84 drawings of the planet made with the 3-foot reflector of Lord Rosse's Observatory, Parsonstown, in the years 1881 to 1886. The drawings have been reproduced without alteration or retouching by a photo-mechanical process. The special feature of the memoir is the great amount of detail shown in the drawings.

(3) "On the Belts and Markings of Jupiter." By N. E. Green (*Mem. R.A.S.* vol. xlix. 1889). This paper presents the conclusions which the author has deduced from the careful study of *Jupiter* during every opposition from 1859 to 1887, and from the comparison of hundreds of drawings. The paper is accompanied by 21 drawings showing an immense amount of detail and much delicate gradation of colour. The special feature of the paper is the evidence presented as to the relations of the light and dark markings, and the inferences drawn as to the physical condition of the planet.

(4) "Zenographical Fragments. No. 1. The Motions and Changes of the Markings on Jupiter in the Apparition of 1886–87." By A. Stanley Williams. This volume contains the author's observations during the apparition of 1886–87, and is illustrated by 52 diagrams. Its special feature is the determination of the rotation period of *all* the distinctive markings of the planet for which it was possible to effect it, and it contains, therefore, very full observations of the times of transit across the central meridian of a great number of dark or bright spots.

E. W. M.

Charts of the Constellations.

Mr. Arthur Cottam has recently published a series of charts of the constellations, its purpose being to serve as a companion to the 4th edition of the late Mr. Webb's "Celestial Objects for Common Telescopes," and also to Mr. Chambers' edition of the "Bedford Catalogue," to which end the author has incorporated the whole of the stars in Lord Crawford's summary of the "Dorpat Catalogue," together with about one thousand multiple and variable stars from the "Pulkowa Catalogue" and those of Mr. Burnham.

The series consists of 36 charts, each showing one entire constellation and parts of those adjoining, projected conically, and including that part of the celestial sphere which lies between the North Pole and declination 30° S. A special feature of the work is the large scale on which the circles representing the stars are drawn, the object of which is to meet a criticism of Sir J. Herschel that in star charts generally the brighter stars are not sufficiently prominent.

Papers read before the Society from March 1889 to February 1890.

1889.

March 8. On the satellite of *Venus* and its revolution. Professor C. V. Zenger.

On a graphical method for determining the orbit of a binary star. Professor S. Glasenapp.

Discovery of comet Brooks (*a* 1889). W. R. Brooks.

Observations of phenomena of *Jupiter's* satellites, made at Windsor, New South Wales, in the year 1888. John Tebbutt.

Observations of the variable star S (10) *Sagittæ*. J. E. Gore.

Observations of the planet *Iris* and comparison stars made with the meridian circle at Dunsink. A. A. Rambaut.

Photographic analysis of the great nebula M 42 and 43 and *h* 1180 in *Orion*. Isaac Roberts.

Preuves de la Nutation diurne : mode d'observation propre à la mettre en évidence en une seule soirée. Professor F. Folie.

Observations of comet *f* 1888 (Barnard) made at Stonyhurst College Observatory. Rev. W. J. Crofton.

A new pair-mirror equatoreal arrangement. Rev. A. Freeman.

On the determination of normal places. Lieut.-Gen. J. F. Tennant.

On the orbit of comet I. 1888 (Sawerthal). Lieut.-Gen. J. F. Tennant.

Observations of comet Barnard (September 2, 1888), and comet Barnard (October 30, 1888), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Note on a red star. E. J. Stone.

The Greenwich standard right ascensions for 1880. A. M. W. Downing.

Spectroscopic observations of sundry stars and comets made at the Royal Observatory, Greenwich, chiefly in the years 1887 and 1888. E. W. Maunder.

On the value of a scale of density on a photograph. Captain W. de W. Abney.

Note on the law of increase in diameter of star discs on stellar photographs with duration of exposure. H. H. Turner.

Note on the spectrum of the great nebula in *Orion*. E. W. Maunder.

April 12. On an error in Brünnow's formulæ for differential refraction in distance and position angle. W. H. Finlay.

Observations of comets made at the Orwell Park Observatory in the years 1888–89. J. I. Plummer.

The trapezium of *Orion*. S. W. Burnham.

Probable errors of Greenwich determinations of right ascension at different zenith distances. A. M. W. Downing.

On the proper motion of 85 *Pegasi*. J. E. Gore.

On the photographs of the corona at the solar eclipse of January 1, 1889. Professor E. S. Holden.

Photographs of the nebulæ M 81, 82, and a nebulous star in *Ursa Major*. Isaac Roberts.

A catalogue of the stars of the IV. type. Rev. T. E. Espin.

Note on an error in Le Verrier's "Tables du Soleil." R. T. A. Innes.

On a method of supporting a large mirror when silvering. Edward Crossley.

May 10. Photographs of the nebula M 51 *Canum Venaticorum*. Isaac Roberts.

Mean areas and heliographic latitudes of Sun-spots, 1874 to 1888, deduced from photographs taken at Greenwich, at Debra Dûn, India, and at Mauritius. Communicated by the Astronomer Royal.

Parallel photographs of the spectra of the Sun, of iron, and of iridium, from H to near D; also separate photographs of the spectrum of titanic iron ore. F. Maclean.

Ephemeris for physical observations of the Moon. A. Marth.

Observations of the planet *Iris* and comparison stars made with the transit circle of the Radcliffe Observatory, Oxford, during the opposition of 1888. Communicated by E. J. Stone.

Observations of Terby's white spot on *Saturn's* ring. A. A. Common.

June 14. On the orbit of *Sirius*. J. E. Gore.

Note on the nebulous star in Mr. Roberts's photograph of 81 and 82 Messier *Ursæ Majoris*. Herbert Ingall.

Photographs and drawings of the Sun. Rev. S. J. Perry.

Comparison of the spectrum between C and D of a Sun-spot observed May 27, 1884, with another of May 7, 1889. Rev. S. J. Perry and Rev. A. L. Cortie.

Observations of the spectrum of *Uranus*. A. Taylor.

Nov. 8. On the close conjunction of *Mars* and *Saturn* near *Regulus*, September 19, 1889. A. Marth.

On the eclipse of *Iapetus* by *Saturn* and its ring system, November 1–2, 1889. A. Marth.

The photographic spectrum of the nebula of *Orion*. (Extract from a letter to Mr. Knobel.) Dr. W. Huggins.

The spectra of *Uranus* and *Saturn*. Dr. W. Huggins. (Extract from a letter to Mr. Knobel.)

The nebula G. C. 2091. E. E. Barnard.

Discussion of the observations of the Sun made with the Washington transit circle during the years 1875–83, inclusive. A. M. W. Downing.

Ephemeris of the satellites of *Saturn*, 1889–90. A. Marth.

Suggestions as to a new general catalogue of stars. G. F. Chambers.

Ephemeris of the satellite of *Neptune*, 1889–90. A. Marth.

Catalogue of 918 radiant points of shooting stars observed at Bristol. W. F. Denning.

Catalogue of bright meteors observed at Bristol during the years 1877 to 1889 inclusive. W. F. Denning.

Preliminary spectroscopic survey of southern stars made at the Melbourne Observatory with a Maclean direct-vision spectroscope on the 8-inch equatoreal. Communicated by R. L. J. Ellery.

Observations of comets *d* 1889 (Brooks) and *e* 1889 (Davidson) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On some of the features of the arrangement of stars in space. Professor E. S. Holden.

Conjunction of *Mars* and *Saturn*, September 20, 1889. Major S. H. Maxwell.

Observations of comet *e* 1889 (Davidson) made at the Melbourne Observatory with the South equatoreal and dark field micrometer. Communicated by R. L. J. Ellery.

On the proper motion of the double star South 503. J. E. Gore.

Observations of comet *e* 1889 (Davidson) made at the Sydney Observatory with the 11½-inch equatoreal and filar micrometer. Communicated by H. C. Russell.

Note to accompany a drawing of the Milky Way. Dr. O. Boeddicker.

The colours of stars. F. W. Levander.

Results of double star measures at Windsor, New South

Wales, during the years 1886, 1887, and 1888. John Tebbutt.

The orbit of comet III., 1888. Lieut.-Gen. J. F. Tennant.

Occultation of *Jupiter* by the Moon, August 7, 1889, observed at Forest Lodge, Maresfield. Captain W. Noble.

Note on solar spots in high south latitudes. Rev. S. J. Perry.

Discussion of Greenwich north polar distances of *Polaris* and other stars, with reference to corrections for temperature and humidity. W. G. Thackeray.

Note on the bright line spectra of R *Andromedæ* and R *Cygni*, and on the suspected bright lines in R *Cassiopeiæ*, and on the spectrum of W. *Cygni*. Rev. T. E. Espin.

Ephemerides of the satellites of *Saturn*, 1889–90 (conclusion). A. Marth.

Note on the determination of stellar parallax by the aid of photography. Professor C. Pritchard.

Occultation of the planet *Jupiter* and its satellites by the Moon, August 7, 1889, observed at the Radcliffe Observatory, Oxford. E. J. Stone.

Observations of *Mars* and *Saturn* at their conjunction, September 19, 1889, made at the Royal Observatory, Greenwich. E. W. Maunder.

Brooks's Comet. J. I. Plummer.

Dec. 13. Areas of faculæ and Sun-spots, compared with diurnal ranges of magnetic declination, horizontal force, and vertical force, as observed at the Royal Observatory, Greenwich, in the years 1873 to 1888. Communicated by the Astronomer Royal.

Mean daily area of Sun-spots for each degree of solar latitude for each year from 1874 to 1888 as measured on photographs taken at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of occultations of *Jupiter* by the Moon, August 7, 1889, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

The late occultation of *Jupiter*. Rev. S. J. Johnson.

On the orbit of Struve 228. J. E. Gore.

Spectra of southern stars observed at the Melbourne Observatory with the Maclean direct-vision spectroscope, attached to the South equatoreal. No. II. Communicated by R. L. J. Ellery.

Spectroscopic observations of the motions of stars in the line of sight, made at the Temple Observatory, Rugby. G. M. Seabroke.

Ephemeris for physical observations of the Moon, January 1 to July 1, 1890. A. Marth.

Note on the spectrum of the Sun-spot of June, 1889. Rev. A. L. Cortie.

A method of recording the transits of stars by photography. W. E. Wilson.

1890

Jan. 10. The photographic apparatus of the great equatoreal of the Lick Observatory. Professor E. S. Holden.

Observations of the eclipse of *Iapetus* in the shadows of the globe, crape ring, and bright ring of *Saturn*, November 1, 1889. E. E. Barnard.

Observations of occultations of stars by the Moon, and phenomena of *Jupiter's* satellites made at the Royal Observatory, Greenwich, in the year 1889. Communicated by the Astronomer Royal.

Ephemeris for physical observations of *Mars*, 1890. A. Marth.

Ephemeris of the satellites of *Uranus*, 1890. A. Marth.

Ephemeris of the satellites of *Mars*, 1890. A. Marth.

The structure of the sidereal universe. T. W. Backhouse.

Spectroscopic results for the motions of stars in the line of sight obtained at the Royal Observatory, Greenwich, in the year 1889. No. XIII. Communicated by the Astronomer Royal.

List of Public Institutions and of Persons who have contributed to the Library, &c., since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The French Government.
British Association for the Advancement of Science.
British Horological Institute.
Camera Club.
City of London College.
Geological Society of London.
Institute of Civil Engineers.
Meteorological Office.
Photographic Society of Great Britain.
Physical Society of London.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Society of London.
Royal United Service Institution.
Society of Arts.
University College, London.
Zoological Society of London.
Belfast Natural History and Philosophical Society.
Birmingham Philosophical Society.
Bristol Museum and Library.
Cambridge Philosophical Society.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Dulwich College Science Society.
Dunsink Observatory.
Edinburgh, Royal Observatory.
Kew Observatory.
Leeds Philosophical and Literary Society.
Liverpool Astronomical Society.
Manchester Literary and Philosophical Society.
Middlesex Natural History and Science Society.

Oxford, Clarendon Press.
Oxford, Radcliffe Trustees.
Oxford University Observatory.
Rugby School Natural History Society.
Stonyhurst College Observatory.
Truro, Royal Institution of Cornwall.
Amsterdam, Royal Academy of Sciences.
Batavia Magnetical and Meteorological Observatory.
Berlin, German Transit of *Venus* Commission.
Berlin, Physical Society.
Berlin, Royal Academy of Sciences.
Berlin, Royal Observatory.
Berlin, Royal Prussian Geodetic Institute.
Berne University.
Bologna, Royal Academy of Sciences.
Bombay Branch of the Royal Asiatic Society.
Bombay, Government Observatory.
Bonn, Royal Observatory.
Bordeaux, Society of Physical and Natural Sciences.
Boston, American Academy of Arts and Sciences.
Brisbane, Queensland Branch of the Royal Geographical Society of Australasia.
Brussels, Royal Academy of Sciences.
Brussels, Royal Observatory.
Buda-Pesth, Hungarian Academy of Sciences.
Buenos Ayres, Argentine Meteorological Office.
Calcutta, Asiatic Society of Bengal.
Canada, Geological and Natural History Survey.
Cape of Good Hope, Royal Observatory.
Carlsruhe Observatory.
Coimbra Observatory.
Copenhagen, Royal Academy of Sciences.
Cordoba, Argentine National Observatory.
Cracow, Academy of Sciences.
Delft, Polytechnic School.
Dijon, Academy of Sciences, Arts and Letters.
Geneva, Society of Physics and Natural History.
Göttingen, Royal Society of Sciences.
Haarlem, Teyler Museum.
Halle, Leopold-Caroline Academy of Naturalists.
Hamburg, Mathematical Society.
Harvard College Astronomical Observatory.
Haverford College Observatory.
Helsingfors, Geographical Society of Finland.
Helsingfors Observatory.
Helsingfors, Society of Sciences of Finland.
Hong Kong Observatory.
International Geodetic Association.
Italian Meteorological Society.
Japan, Seismological Society.

Kalocsa Observatory.
Kasan, Observatory of the Imperial University.
Leghorn, Technical and Nautical Institute.
Leipzig, Astronomical Society.
Leipzig, Royal Saxon Society of Sciences.
Lick Observatory of the University of California.
Lund Observatory.
Madrid Observatory.
Madrid, Royal Academy of Sciences.
Marseilles, Flammarion Scientific Society.
Mauritius, Royal Alfred Observatory.
Melbourne Observatory.
Milan, Royal Observatory.
Moncalieri Observatory.
Montreal, Royal Society of Canada.
Montsouris Observatory.
Moscow, Imperial Society of Naturalists.
Moscow Observatory.
Munich, Royal Bavarian Academy of Sciences.
Munich, Royal Observatory.
Naples, Royal Academy of Sciences.
Natal Observatory.
Nebraska University.
Neuchatel, Society of Natural Sciences.
Ottawa, Canadian Meteorological Office.
Palermo Royal Observatory.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.
Paris, Bureau of Longitude.
Paris, General Depôt of Marine.
Paris, International Committee of Weights and Measures.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society of France.
Paris, Polytechnic School.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Potsdam Astrophysical Observatory.
Prague, Imperial Observatory.
Pulkowa Observatory.
Rio de Janeiro Observatory.
Rome, Central Meteorological Office.
Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy *dei Lincei*.
Rome, Royal Academy *dei Lincei*.
St. Petersburg, Imperial Academy of Sciences.
San Fernando Observatory.
San Francisco, Astronomical Society of the Pacific.
San Francisco, University of California.
Stockholm Observatory.

Stockholm, Royal Swedish Academy of Sciences.
Sydney, Government Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya Observatory, Mexico.
Taschkent Observatory.
Tasmania, Royal Society.
Toronto, Canadian Institute.
Toulouse, Academy of Sciences.
Turin, Observatory of the Royal University.
Turin, Royal Academy of Sciences.
Vienna, Austrian Geodetic Commission.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Observatory.
Washington, National Academy of Sciences.
Washington, Office of the American Ephemeris.
Washington, Smithsonian Institution.
Washington, United States Coast and Geodetic Survey
Washington, United States Naval Observatory.
Yale College Observatory.
Zurich, Central Meteorological Institute.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomische Nachrichten."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of "Engineering."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Le Galilée."
Editor of the "Journal du Ciel."
Editor of "Die Naturwissenschaftliche Rundschau."
Editor of "Die Naturwissenschaftliche Wochenschrift."
Editors of the "Observatory."
Editor of the "Sidereal Messenger."
Editor of "Sirius."

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Mons. Ch. Fievez.
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Prof. E. Loomis.
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Lieut.-Col. J. Waterhouse.
F. R. Wegg-Prosser, Esq.
Mrs. W. H. Wells.
Prof. G. D. E. Weyer.
A. Stanley Williams, Esq.
Prof. W. C. Winlock.
Dr. R. Wolf.
Prof. C. A. Young.
Prof. C. V. Zenger.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :—

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Lieut.-Gen. J. F. Tennant, C.I.E., R.E., F.R.S.

Vice-Presidents.

Capt. W. de W. Abney, C.B., R.E., D.C.L., F.R.S.
Arthur Cayley, Esq., M.A., Sc.D., LL.D., D.C.L., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.
Lieut.-Col. G. L. Tupman, R.M.A.

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A. A. Common, Esq., F.R.S.

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E. B. Knobel, Esq.

Foreign Secretary.

William Huggins, Esq., LL.D., D.C.L., F.R.S.

Council.

J. C. Adams, Esq., M.A., Sc.D., LL.D., D.C.L., F.R.S., Lowndean Professor of Astronomy, Cambridge.
Sir R. S. Ball, LL.D., F.R.S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland.
Hon. Sir James Cockle, M.A., F.R.S.
Edwin Dunkin, Esq., F.R.S.
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.
George Knott, Esq., B.A., LL.B.
Capt. William Noble.
W. E. Plummer, Esq., M.A.
Isaac Roberts, Esq.
E. J. Spitta, Esq.
E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.
H. H. Turner, Esq., M.A., B.Sc.